Strategies for Sustainability

Peter A. Wilderer
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Konrad Oexle *Editors*

Strategies for Sustainability of the Earth System

Springer

Strategies for Sustainability

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Sustainability assessment and reporting
The role of scientific analysis in decision-making
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Foreword

In 2019, scientists of various disciplines, entrepreneurs, and members of governmental and non-governmental institutions met at the TUM Science and Study Center in Raitenhaslach for a workshop organized by the International Expert Group on Earth System Preservation (IESP) in collaboration with the TUM Emeriti of Excellence (EoE). This group of 40 outstanding scientists convened to discuss and propose realistic, workable solutions for the literally burning issues caused by the degradation of the Earth system, manifested as loss of biodiversity and rapid climate change. In keeping with the urgency of the problems, a drastic title was given to the workshop. The title "Violated Earth—Violent Earth. Causes and effects of human's misdemeanour and Nature's power" leaves no doubt that uncontrolled anthropogenic effects inflict the threatening natural processes, which we are experiencing more and more already.

During their intense group discussions, the participants drafted twelve recommendations for action. To arrive at concrete recommendations has become a signature of IESP workshops. They address decision makers in science, politics, and industry. The recommendations for a Sustainable Management of the Earth System as given by the 2019 workshop in Raitenhaslach can be found in the closing chapter of this volume.

This workshop is part of the action agenda of the Technical University of Munich (TUM) aiming at creating impact in a changing world and helping to shape sustainable developments. Next to research, teaching, and student activities on sustainability, the editors and contributors to this volume have all been drivers of our sustainable transformation. Meanwhile, sustainability has become a strategic priority of TUM. Restoring a sustainable balance between environment, economy, and society will be of utmost importance in the twenty-first century. We have decided to embrace this challenge because it is our social responsibility as a university to apply the intellectual and technological capacities for proposing and shaping a sustainable future. Whereas TUM's efforts in research and teaching have generated a lot of impact already, we decided to embrace it on a strategic level and with a whole-institution approach. Our ongoing efforts are manifested on for example by the introduction of our TUM Sustainability Office and our TUM Taskforce Sustainability. In fact, it is our joint efforts that determine how our future will look like.

Therefore, please spread the word among your networks and let us work together beyond the frontiers of disciplines, cultures, and our own thinking—this is our joint responsibility.

Yours
Thomas F. Hofmann
President of the Technical University of Munich
Munich, Germany

Message from the Desk of the Bavarian State Minister for Environment and Consumer Protection

Dear Readers

The basis of this book is three days of highly concentrated expert work. During its workshop entitled "Violated Earth—Violent Earth. Causes and Effects of Human's Misbehavior and Nature's Power," in March 2019, the International Expert Group on Earth System Preservation (IESP) put the global threats of our time on the agenda. And with these threats raised the question of how mankind in its dual role of perpetrator and victim can counteract them in time.

The effects of human action since industrialization are unmistakable: They can be felt in the water, on land, and in the air. In water, because sea levels are rising; on land because soils are losing their ability to function, resources are running out, and biodiversity is dwindling; and in the air, because hurricanes threaten to become an everyday event in times of Climate Change. Thus far, the well-known analysis.

The participants in the workshop "Violated Earth—Violent Earth" went far beyond this analysis with their work. They asked themselves the question about a specific, objectifiable need for action and—even more difficult—how this need for action is compatible with the way people live and work in the twenty-first century. The area of tension highlighted here could hardly be more complex and is very well known to those in positions of responsibility in politics and business. It encompasses the socially desired and the technically necessary as well as what is technically feasible and politically communicable. Implicitly, this field of tension always challenges the core legitimacy of a democratic system—namely the ability to strike a balance between conflicting interests and to bring growth and development into sensible equilibrium. Ultimately, we renew this legitimacy if we succeed in reconciling the interests of our injured planet with those of human civilization.

These conference proceedings certainly do not provide a finished action plan to reconcile these interests, but it provides invaluable stimuli for clear and comprehensibly justified pointers towards the direction in which our path must lead us. Once again, the IESP expert network has done a great job. It has taken up an appeal by

Ernst Ulrich von Weizsäcker that must be both self-insurance and aspiration: “Come on!”. I would like to thank you all for this work, express my hope it will continue, and wish you a stimulating read!

Yours
Thorsten Glauber
Bavarian State Minister for Environment and Consumer Protection

Editorial: A Journey Through the Book

Introduction

Climate protection, biodiversity preservation, and economic resilience are major requirements to build a sustainable foundation for future societies. This volume provides a comprehensive overview of political, ecological, medical and philosophical approaches towards a scientifically sound understanding of the man-made environmental crises, and suggestions for avoiding unnecessary threats. A workshop held at the premises of the TUM Science and Study Center, Raitenhaslach on March 20–22, 2019 addressed that topic under the title "Violated Earth, Violent Earth." This workshop was inspired by James Lovelock's book "The Revenge of Gaia" [3]. While certainly not taking the meaning of "revenge" literally in the sense of intentional retaliation, both Lovelock and the workshop in Raitenhaslach used the term to emphasize the detrimental reactions of the Earth system. Pushed out of the established ecological balance on a global level, the strong dynamics of the system deteriorate living conditions and cause catastrophic events. The sheer number of people living on Earth is a major cause of this dysbalance. People account for 36% of the entire mammalian biomass, and their livestock, especially cattle, for another 60%, leaving only 4% to wild mammals [1]. While Homo sapiens has always significantly changed ecosystems [2], the effect has become overwhelming due to exponential population growth.

However, the rise of modern civilization also engendered far-reaching scientific knowledge about the complex processes of the world we live in. It is our responsibility to expand that knowledge further, to share it across all continents, and to utilize it for preventing or at least damping the disastrous reactions of the Earth system. The workshop in Raitenhaslach tried to meet that responsibility. Thereby, it picked up the thread of the latest report to the Club of Rome [4]. Of note, this report suggests to embed a science-based approach to the world in a renewed "philosophy of balance." This philosophy addresses all aspects of human life and emphasizes everybody's responsibility for the common good, thus amounting to a "New Enlightenment." Indeed, the latter appears to have started already. People worldwide are determined to understand the interrelations in our world, to invest in balanced, sustainable developments, and to aim for a good future of all mankind.

Focus Areas

The workshop brought together prominent representatives from a broad spectrum of disciplines, including philosophers, physicists, systems theorists, life scientists, engineers, and economists. Their goal was twofold. They aimed for shaping or improving specific sustainability strategies in terms of circular economy, ecological governance, multi-lateral politics, advanced technologies, pollution prevention, public health, and lifestyle changes. Moreover, they addressed the preconditions of a cultural turn to sustainability including philosophical, systems theoretical, socio-economic, and educational approaches, which are most relevant in a strategic sense for humanity's development. Four groups worked on the four main topics presented below in parts A–D. Part E finally presents the joint recommendations for action that aim to provide readers with science-based information for sustainable decisions.

Part A ("General Thoughts") starts with Ernst Ulrich von Weizsäcker, who summarizes the recent report to the Club of Rome. In the overpopulated world of the Anthropocene, ecological systems cannot buffer human activity anymore. Achieving an ecological balance is, therefore, a major challenge for humanity and fundamental to all disciplines, from contemporary philosophy to sustainability in economics. For both, he provides ample, science-based recommendations towards a circular economy and vastly increased productivity of resources. Skepticism about the anthropogenic causes of the ecological crisis, even among scientists, still hinders tangible action. Franz Mauelshagen and Walter Pfeiffer analyze where skepticism about Climate Change derives from. Even if such skepticism is overcome, the autopoietic closure of social subsystems may preclude them from developing a coordinated response to the challenge as Konrad Oexle argues by revisiting Luhmann's systems theoretic analysis. Systems theory, albeit from a different branch, also underlies the contributions of Ortwin Renn, Patrick Dewilde, and Klaus Mainzer. Renn provides an overview of the risks and potential tipping points. Mainzer outlines that artificial intelligence can help to monitor and steer the complex and dynamic Earth system but requires causal explainability and governance. Dewilde develops the concept of ecological ethics as a layer of behavioral control in the self-regulating Earth system, created by human intelligence, which emerged in that very system and now tries to achieve ecological health of the Earth. Eckehard Binas looks at man as the created self-creator who is driven to and even attracted by the borders of emergent novelty despite being affected by a blurred and biased self-recognition. Instead of moralistic conservatism, Binas calls for a solid and confident philosophy of culture as a contribution by the humanities, which have a long tradition of examining the societal part of the Earth system.

Part B ("Ecology: A Key Resource") commences with a critical review of the status of water, soil, and ecosystems. Martin Grambow, the leader of an extended team of authors, delineates how our ecological choices relate to the question in which world we want to live in the future. Anastassia M. Makarieva, a close collaborator of the late Victor Gorshkov and his groundbreaking work on the biotic pump of forestal water circulation, demonstrates the importance of cross-disciplinary synthesis for the preservation of natural ecosystems and the habitability of the Earth. Peter A. Wilderer and Michael von Hauff explain the importance of resilience thinking in the process of keeping the Earth system at a sustainable level. Resilient socio-ecological systems withstand perturbations such as pandemics or infections of forests and continually rebuild and renew themselves. Mathis Wackernagel, known for his Global Footprint Network (GFN), shows that our current dealing with natural resources resembles a so-called "pyramid scheme," which necessarily ends in a total loss for almost all partakers. He presents strategies to halt this fatal scheme. Organizational changes for sustainability provide vast opportunities, as Franz-Theo Gottwald exemplifies in detail for the case of sustainable agriculture. Another team of authors led by Martin Grambow takes a close look at the effects of changes in the water system using the example of the German State of Bavaria. Incidentally, the debates among the participants of part B reveal divergent assumptions on major notions of systems theory such as state, complexity, or resilience. This divergence prompted the contributors Dewilde, Wilderer, von Hauff, Makarieva, Wackernagel, and Mainzer to an in-depth discussion and clarification of the use of those notions, inviting the readers to take critical positions themselves.

Part C ("The Human Health Dimension") refers to the health problems generated by the dysbalanced ecological systems. A striking example is presented by Heidrun Behrendt and Johannes Ring who demonstrate how severe episodes of allergic diseases increase in frequency as a result of plant stress induced by Climate Change. It would be insufficient, however, to attribute only a reactive role to health care. Medicine is a major part of civilization and of civilization's impact on Nature. Thus, the extension of the human life span during the last century bases on the unsustainable use of natural resources. To confine these repercussions, Hans-Peter Zenner calls for an evidence-based application of medicine, especially in the multimorbid old patients, and for effective disease prevention through an improved public health system. His analysis concurs with Ulrich Hildebrandt's, which explains how improved nutrition, e.g. by reducing meat consumption, may not only promote individual health, but reduce the environmental impact of industrial agriculture. Oncology is a part of medicine that will grow exponentially in an aging population. Michael Molls, Hendrick Dapper, and Hanno Specht show that radiation therapy—besides surgery,—is the most effective and cost-efficient treatment of solid cancers. In contrast to Zenner's postulates, they provide a criticism of evidence-based chemotherapy, which has produced little progress since 70 years, compared to other parts of medicine. For neuropediatrics, Ingo Borggräfe outlines the striking success of gene-regulatory treatment of spinal muscular atrophy, deep brain stimulation in patients with dystonia, and external movement habituation in patients with cerebral palsy. Impressive as they are, such expensive therapies create problems in terms of equitable allocation and sustainable use of natural resources. This generates a temptation to touch upon the genetic level of Nature, that is, upon the human germline to prevent diseases primarily. However, genetic modifications that autonomously expand beyond individual organisms also have enormous potential for a harmful backlash. Moreover, genetic modification may be ill-informed, if not even stupid, as recently demonstrated by the first case of CRISPR/Cas application on the human germline aiming for protection against a paternal HIV infection. Some ignorant expectations also issue from insights in epigenetics. Konrad Oexle reviews the state of the art in the field and explains why epigenetics is not likely to drive the desired transformation of mankind into an altruistic, ecologically compatible species. Great expectations, illusions, fears, and dangers not only coincide in the case of genetics. An ambivalence of potential benefit and harm is also present in computational technology. Florian Heinen addresses the example of smartphone use in early childhood. It may lead to various negative consequences, from myopia to problems of social interaction, while opening a new channel for early, pre-lingual interaction with the world at the child's hand. Artificial intelligence is the latest development in computational technology. Radu Grosu provides a fascinating overview of how AI can improve precision medicine in radiation oncology or cardiology and how it supports innovations in disease prevention as well as efficient use of resources.

Part D ("Towards a New Enlightenment") closes the circle back to Part A but with an emphasis on the necessary adaptations of our philosophical and political stance in the future. The perspectives of sociology, philosophy, and theology on the necessary "New Enlightenment" were presented by Markus Vogt, Andreas Klinke, and Jörg Wernecke. At its core, this enlightenment must provide all mankind with a fundamental attitude of responsibility about the Earth system. Paul Beckh, a law student in his early twenties, describes how the "Friday for Future"-generation is already taking over that responsibility. Concrete action is possible in many quarters, however. Hans-Peter Zenner emphasizes that the discipline of public health provides a suitable political toolbox to reduce anthropogenic violation of the Earth. All fields of human activity need to aim for sustainable consumption. Michael von Hauff and Monika Schappert show us how this notion can replace a merely quantitative interpretation of consumption in the economy. To conclude, Axel Kleidon describes the general, that is, thermodynamic preconditions of any possible development of the Earth system.

Konrad Oexle
Michael Molls
Martin Grambow
Peter A. Wilderer
Agnes Limmer

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Abbreviations

CoR	Club of Rome, Brussels, Belgium
EoE	TUM Senior Excellence Faculty, Technical University Munich, Munich, Germany
IAS	TUM Institute for Advanced Studies, Garching, Germany
IASS	Institute for Advanced Studies on Sustainability, Potsdam, Germany
IESP	International Expert Group on Earth System Preservation, TUM Institute for Advanced Study, Garching, Germany
LfU	Bavarian Environment Agency, Augsburg, Hof, Germany
LMU	Ludwig-Maximilians-University Munich, Munich, Germany
MPI	Max Planck Insitute for Biogeochemistry, Jena, Germany
StMUV	Bavarian State Ministry of the Environment and Consumer Protection, Munich, Germany
SW	Schweisfurth Stiftung (Foundation), Munich, Germany
TUM	Technical University of Munich, Munich, Germany

General Thoughts

The Anthropocene Turns Out to be a Disaster for the Earth: Few Options Remain to Change Course

Ernst Ulrich von Weizsäcker

Abstract We humans have filled the world, leaving almost no corner in its pristine status. Our consumption is based on the treasures of nature. We must distinguish today's *Full World* from the earlier times of the *Empty World*. The Full World is now called the Anthropocene, the era humans govern the world, leaving ever less room for nature. Two main causes of the transition from empty to full should be distinguished: the increase of human population and the steep increase of per capita consumption. When confronted with the need of healing ecological disasters, the societal consensus sounds like "We need more growth". We are largely aware that global warming is a dangerous disease but the remedy offered against the disease systematically makes it worse. Such errors can be interpreted as signs of a *fundamental philosophical crisis*. This is also the motto, as we see it, of the Encyclical Letter *Laudato Si'* by Pope Francis. The new Club of Rome book *Come On!* tries to show the philosophical way out. We are blaming dogmatism—including the dogma of quantitative growth—and propose a philosophy of balances. We need stable balances between humans and nature, short-term and long-term benefits, speed and stability, and between justice and awards for achievement.

Keywords Anthropocene · Full World · Population increase · Philosophical crisis · Balance against dogmatism

1 The Full World is Called the Anthropocene

The *6th Global Environmental Outlook (GEO 6)*, published in early 2019 by UN Environment [13], shows that the Global Living Planet Index is steadily deteriorating! The reason, quite simply, is that we humans have filled the world, leaving almost no corner in its pristine status, and that our exponentially rising consumption is based on the treasures of nature. Herman Daly, the former Chief Economist of the World Bank, suggests to distinguish today's "Full World" from the earlier times—until roughly

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1950—of the "Empty World." The Empty World was ecologically mostly healthy, or sustainable. That sustainability is largely gone in our new era, the Full World.

Other people use similar observations to define the new geological era, called the Anthropocene, the era during which Homo sapiens governs the world, leaving ever less room for the "wild" nature. Figure 1 contains 24 small graphs showing that until 1950, the growth trends were still modest and mild but got explosive after that year. The red coloured graphs represent the world population (upper left corner) and eleven consumption trends. The green graphs show Nature's response. The higher the line, the bigger the associated damages.

2 The Club of Rome Report "ComeOn!", and the Climate Crisis

TheClub of Rome, in its recent strategic Report *Come On!* (Ulrich 2018), made use of Herman Daly's distinction between the Empty World and the Full World. The famous initial Club of Rome Report *The Limits to Growth* (Meadwos, Meadwos, Randers, Behrens III.) had already given an inkling of catastrophic dangers to emerge from continued further growth. But nothing like the red coloured graphs of Fig. 1 was predicted in that report.

Come On! has three parts showing two very different meanings of its title:

Part One: C'mon! Don't Tell Me the Current Trends Are Sustainable!

Part Two: C'mon! Don't Stick to Outdated Philosophies!

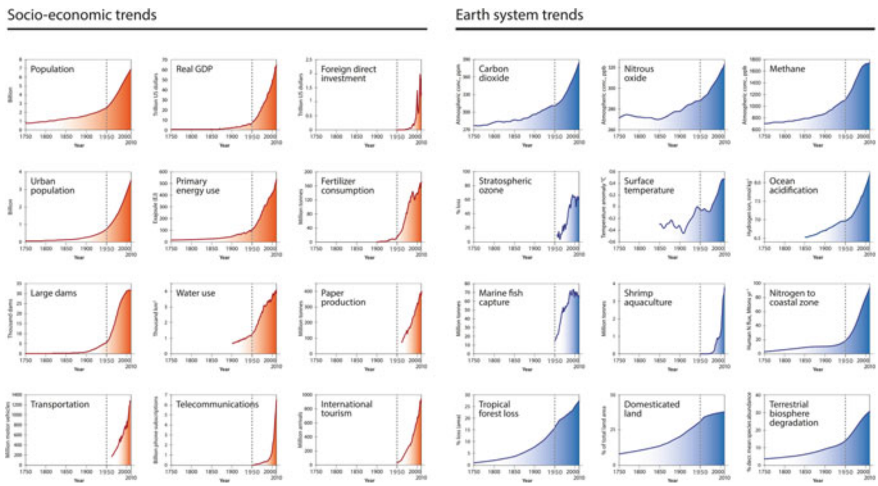

Fig. 1 The "Anthropocene" began around 1950 (thin vertical line in each sub-picture) *Source* IGBP [18], via futureearth.org, Steffens et al. [18]

Part Three: Come On! Join Us on an Exciting Journey Towards a Sustainable World!

Let us start with Part One showing the non-sustainability of the current trends.

What is now closest to nearly everybody's mind is the climate crisis. In earlier years, we have seen signs of slowly changing weather conditions, but they could be interpreted as the kind of fluctuations that had been recorded since earlier centuries. But 2018 was different withyphoons in East Asia, Hurricanes in the Caribbean and North America, floods in Nigeria and other African countries, and unprecedented droughts in Europe and Siberia. 28 big wildfires in Sweden alone. Europe had its hottest year documented ever, 1.78 °C warmer than average.

A 15 years old girl in Sweden, Greta Thunberg, began a school strike protesting against trends and action bound to destroy her generation's future. Swedes agree that had she began her strike a year earlier most people in her country would have laughed at her, but in 2018 the vast majority said that Greta was completely right.

Wildfires, hurricanes, and floods are the scourges on land. What is likely to become a lot scarier is the prospect of sea level rise! Some 93% of the global warming is actually happening in the ocean water, only 7% on land and in the air. And sea levels have been falling and rising during the Earth's history. Italy during the last Ice Age (20,000 years ago) was some 20% larger than it is today. But during the last hot age (2 million years ago), Italy was only half as large as today.

What is even more disturbing is the fact that the sea level rise can occur in a jump. About 7,700 years ago, the areas now called Labrador and the Hudson Bay were covered by a huge ice mass, roughly equivalent to the ice shield over Greenland. But in a very short time, it must have collapsed mechanically, as Tooley [10] has published. Imagine, a similar break-down would happen with the Greenland ice or the West Antarctic ice sheet, and that, owing to the current warming dynamic, during our century! It could mean a refugee problem a hundred times larger than the one shaking Europe in 2015!

3 Anthropocene: Humans Dominate Everything [9]

There are other unpleasant features of the Anthropocene. Calculating the body weights of land-living vertebrates in three categories leads to the following surprising result: 67% of the bodyweights are domesticated animals, chiefly animals for slaughter, 30% are we humans ourselves, leaving a mere 3% for all wild animals! Is that not shocking?

The main cause of the transition from the Empty World to the Full World is the increase of the human population. Also here, the magic year of 1950 plays a major role. In that year, world population was a little over 2.5 billion. 70 years later, we are three times more: 7.7 billion. What grew even more rapidly was consumption. World GDP grew from ca $2.3 trillion in 1950 to $18.6 trillion (constant dollars).

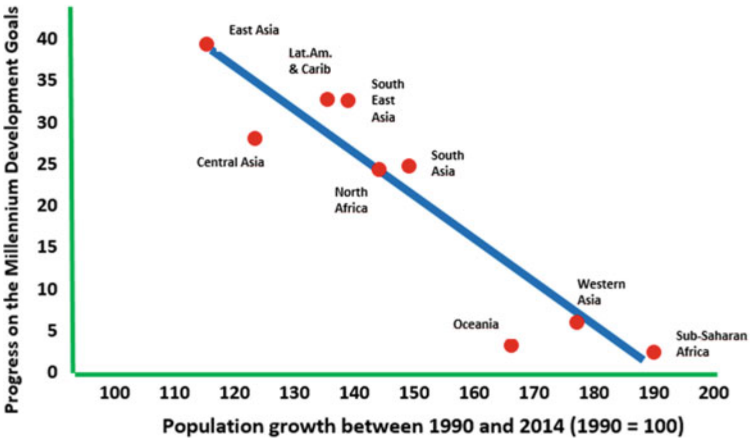

Fig. 2 Regions that managed to stabilize their population were the economic winners, regions with unabated population growth tend to be the losers [14]

Stabilizing population must become one of the most urgent objectives on national agendas and on the international agenda. Fortunately, we now have evidence that regions that managed to more or less stabilize their populations turned out the big economic winners, while those maintaining rapid population growth are the losers, see Fig. 2.

Of course, the causality works both ways: poor countries cannot really afford solid school education and a satisfying pension system. Lack of schooling, notably for girls, tends to lead to unwanted births, and lack of social security can lead to family preference for many children who are expected later to take care of their senescent parents. But the states are gradually becoming aware of the first causality.

4 Philosophical Crisis

Coming back to the climate crisis, we have to ask for policies of mitigating global warming. This has been the chief objective of the annual conferences of the parties of the FCCC, the Framework Convention of Climate Change. But the G77—developing countries—tend to say it was not their duty to curb greenhouse gas emissions but rather to adapt to the risks caused by global warming. And for doing so, they need more money, evidently from the richer countries that are seen as the originators of global warming.

But the more prospering countries too have a tendency of asking for more money when confronted with climate mitigation. This leads to the odd conclusion that all countries cry for more economic growth in order to deal with global warming. That's odd because, in the eight most relevant economic sectors, we observe a clear positive correlation between GDP per capita and CO_2 emissions per capita (Edgar and Peters, 2009). In caricature medical doctors' language, this means: We are largely aware that global warming is a dangerous disease but the remedy we are offering against the disease systematically makes the disease worse.

Such errors can be interpreted as signs of a *fundamental philosophical crisis*. In Part Two of the book, we make clear that we cannot stay in a situation characterized by a global philosophical crisis. We are simply unwilling to accept a situation where the increase of welfare makes global warming worse year by year. Of course, I have been working during the last 25 years on the chances of overcoming that correlation by dramatically increasing energy and resource productivity, e.g. in books like *Factor Five* [15]. But so far, all efficiency improvements have been outpaced by increased consumption rates. So, the philosophical denial of truth goes on.

What is thrillingly reassuring is the Encyclical Letter *Laudato Si'* by Francis [11]. He declares the destruction of our Common Home (the Earth) to a large extent caused by human greed and the current economy with brutal competition, selfishness, and short-term thinking.

In our book *Come On!,* we used the Papal Encyclical as the start of the philosophical debate. But we went further. We looked at the fame of two major thinkers of the late eighteenth century and one from the mid-nineteenth century. Their names are Adam Smith, David Ricardo, and Charles Darwin, all living, according to the above definition in the "Empty World." We looked at what they said and at the typical citations of the three in today's literature and thinking. The devastating result was that all three made revolutionary discoveries that were perfectly correct under the conditions of the time but that they are quoted massively wrong in our globalized Full World.

5 Adam Smith, David Ricardo, and Charles Darwin

Adam Smith discovered that the legitimate selfishness of working and producing traders was actually increasing the "Wealth of Nations". At his time that came as a surprise: why should others benefit from my selfishness? The answer was that it was in the self-interest of the traders to be excellent and efficient, and that the sum of all the products and services made the whole economy ever richer. And the selfishness was limited by the law so that it did would not normally cause illicit damage to others. The geographical reach of the law was identical with the reach of the market. But today, the geographical reach of the market is global and that of the law—where it exists and is enforced—remains largely national. Hence, the rules of the market (maximizing returns on investment) are a lot more powerful than national laws. In fact, under the pressure of global investors, the lawmakers in each country are induced to set the legislation and distribution rules such that investors maximize their returns on investment. That mostly goes to the disadvantage of the poor. Adam Smith would turn in his grave seeing what social and environmental damages today's world markets are causing.

For David Ricardo, international trade among countries was a blessing for all participants and was leading to and honouring some degree of specialization. In effect, such specialization is made for additional welfare. But capital at his time was not moving across borders, with the exception of a couple of guineas traders would carry by themselves. But today, capital is by far the most mobile production factor, much more mobile than physical goods, let alone humans. Today, the virtual money economy uses computerized algorithms allowing for speculation in milliseconds of billions of dollars. The financial markets are enslaving the real economies of all countries, with most of the added value remaining in the pockets of shrewd speculators. David Ricardo would turn in his grave seeing today's global trade and would shout that this is the opposite of what he meant by his expression of the comparative advantages of specialized trades in different countries.

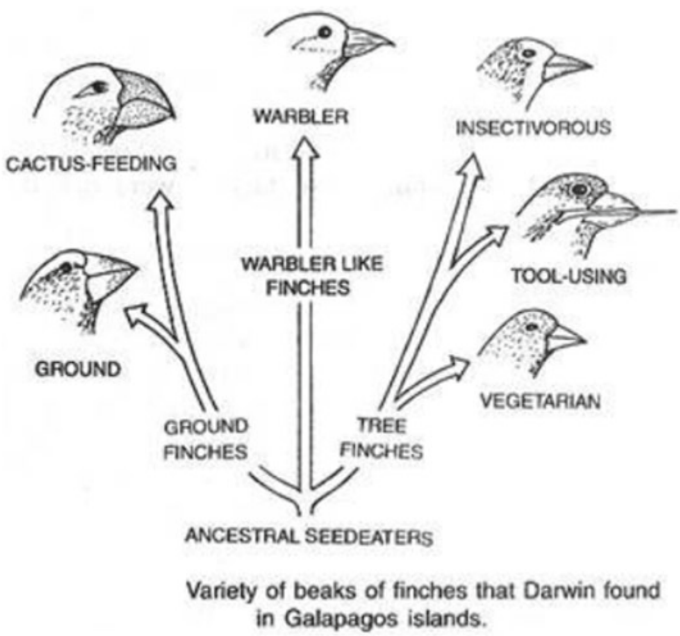

Fig. 3 Evolution of finches on the Galápagos Islands, as imagined by Charles Darwin[1]

[1] After [1].

Charles Darwin was enthused watching the diversity of plants and animals that evolved over the billions of years of our planet's history. He discovered that the competition of species against each other was actually increasing diversity as species found ever new niches of habitats where they could thrive. He also observed that competition let the fittest thrive more than the less fit. But the less fit mostly had a chance of specializing in their respective niches.

He travelled to the Galápagos Islands where he discovered finches that had evolved into specialists for survival under the local conditions. One species had learned to use cactus thorns to extend the length of their beaks allowing them to pick insect larvae from under the bark of trees and bushes. Darwin immediately realized that in the presence of real woodpeckers, finches wouldn't have had a chance of developing this elegant tool use of cactus thorns (Fig. 3). The geographical isolation of the islands was actually helping the evolution of finches.

Modern population Darwinism would add that the mechanism of inheritance of recessive genes was usually preventing the eradication of such genes even if they were representing certain weaknesses compared with the wild-type animals or plants. The conservation of millions of recessive genes was creating huge reservoirs of genetic variance, which could under new stress conditions be extremely valuable for meeting new challenges.

In contrast to this evolutionary theory originating from Charles Darwin, some myths including a primitivistic version of "Social Darwinism" hailing the total victories of the strong lead to the eradication of the weak. By definition, this means diminishing diversity including hopeful options for future challenges. Once more, Charles Darwin would turn in his grave seeing such myths dominating the economic doctrine of selection against the weak.

6 Balance as a Feature of a New Enlightenment

A further step of our philosophical discussion is challenging the dominant role "analytical philosophy" maintains in the Anglo-Saxon scientific world. Analytical philosophy is a useful method for unmasking mountebank charlatans. But it invites for a "reductionist" worldview that is void of systemic thinking. For a living world, it is essential to appreciate systemic diversity, openness for unknown future development, and non-materialistic features in reality.

We felt that balance was an essential feature for appreciating reality. Other than opinionated dogmatism, balance is representing reality around us. Hegel's dialectic philosophy, the African Ubuntu (defining me as the resonance of the community), or the Yin–Yang-dichotomy in Asian cultures were closer to complex reality than simple true/false statements like two times two is four.

In *Come On!*, We offered a number of pairs seemingly contradicting each other but also complementing one another. These are

- Humans and nature. In the *empty world*, that balance was a given. In the *full world*, the Anthropocene, it's a huge challenge. Using remaining natural landscapes, waterbodies, and minerals chiefly as resources for an ever-growing human population and the fulfilment of ever-growing consumption is not balance but destruction.
- Short term and long term. In reality, you need both. The current craze about what's happening right now, the "twitter mentality", regardless of history and of future perspectives, is silly. But so is the exclusive meditation about the past and the far future.
- Public and private. Public goods such as public infrastructures, basic education, a healthy environment, or a functioning legal system can only be guaranteed by the state. The efficient production of goods and services, on the other hand, works best in the hands of the private sector. The total dominance of the state is dictatorship. But totally deregulated markets lead to "Social Darwinism" leaving civil freedoms only to the victorious.
- Female and male. Riane Eisler wrote a pivotal book [12] about early human cultures rather dominated by women and avoiding nonsensical wars. But much of human history is about wars initiated and fought by men. The Yin and Yang symbol means that male and female represent different virtues that are complementary and mutually beneficial. Dominance by one of the two is wrong, but pushing as many women as possible into typical male jobs may also be wrong. Better redefine the typology of jobs.

We go as far as reminding readers that modern physics has formulated the complementarity principle and Heisenberg's uncertainty principle. Two mutually complementary properties cannot be measured exactly at the same time. So, the zeal for exactitude is limited by the laws of physics, not only by immature measurements.

7 Which Options Remain?

The idea of establishing a new Enlightenment may be right but is immensely ambitious, perhaps intractable. It may be of the size of the European Enlightenment from Descartes and Francis Bacon until David Hume, Rousseau, Adam Smith, Kant, and Hegel. But *Come On!* in effect is much more modest. It formulates the gigantic challenge, gives a few hints for the direction of work but then switches to practical politics suitable for averting the most visible disasters.

Part Three of the book as said at the outset invites readers to an exciting journey towards a sustainable world. We look at the climate challenge, energy, transport, agriculture, the circular economy, and the political steps that make progress in the desired direction more lucrative than the current destructive mining of the natural treasures. One principle is that "prices should tell the ecological truth". This is absolutely not the case in today's world. Destroying remaining primeval forests, as President Bolsonaro is promising in Brazil's Pantanal, can make the sugar barons richer but

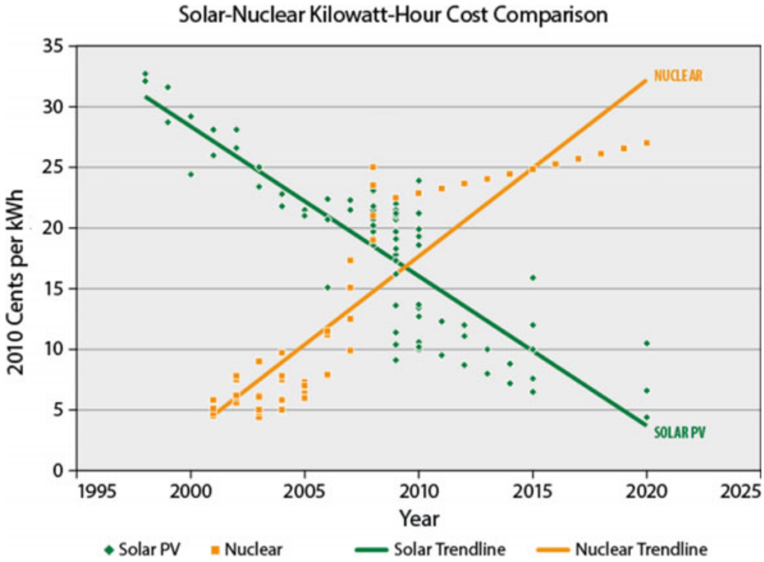

Fig. 4 Solar PV beats nuclear in terms of cost [7]

destroys some of the Planet's most fascinating biotopes possibly irreversibly. Sugar from such destructive operations should be hugely more expensive than sugar from existing plantations or should be plainly banned altogether.

Following the logic of *Factor Five* (Footnote 9), we show that enormous potential exists of producing more useful goods with less damages for nature. A regenerative agriculture can regain biotopes for the animal companions of classical (small scale) farming, such as skylarks, partridges, lapwings, herons, hares, badgers, beavers, or lynxes, and any number of butterfly and other insect species, and myriads of tiny microorganisms and Earthworms in the soil.

The circular economy is not by itself profitable. But if virgin materials become more expensive, it becomes economically reasonable to recycle waste and to remanufacture valuable products such as computers or parts of decommissioned airplanes. Stuchtey et al see a "good disruption" coming, essentially by making the Circular Economy really profitable [8].

The feed-in tariffs law stemming from Germany has led to the surprising situation (see Fig. 4a) that photovoltaic solar energy has meanwhile beaten nuclear energy in terms of cost. Notably, the explosive growth in China of PV manufacturing and installations has brought the cost down much faster than anybody had been expecting.

What may be most important is a re-regulation of financial markets. The deregulation during the 1990s was hailed as the liberation of a big machine of creating worldwide added value. But in the end, it has shifted the balance of power away from the lawmakers to the money-makers and has horrendously weakened democracy. In Come On!, we are offering many ideas. Re-separating commercial and investment banking makes it difficult to use the savings of citizens for highly risky investment speculations. Controlling "money creation" by lending is problematic and risky. Speculation in timeframes of milliseconds using computerized algorithms is in danger of disturbing the real economy and should be curbed. One idea is an absolutely tiny "Tobin Tax" on financial transactions, just large enough to make millisecond speculation unprofitable: If the transaction tax applies to each transaction, the whirlwind sequence of a thousand transactions per second would become prohibitively costly. Ordinary rational-based speculation, by contrast, would not suffer at all.

Other policy ideas in Part Three include a political decision of making the use of natural treasures more expensive in small steps. In order to be socially acceptable, we say the speed of the price increase should be roughly as high as the speed of technological efficiency improvements. Thereby one would avoid more expensive living standards. Special arrangements can be added for very poor families and for industries that cannot change as speedily as the average. The "ping-pong" between efficiency and prices is an exact copy of the ping-pong we had during the magnificent Industrial Revolution between labour productivity and the average wages of workers, leading to a roughly twentyfold increase of labour productivity. And there is no scientific reason to believe that resource productivity or carbon productivity cannot grow equally by a factor of twenty.

Finally, the book also talks about international cooperation and synergies. For the climate crisis, the "budget approach" is explained (WBGU, 2009), which would allocate identical per capita permits of greenhouse gas emissions to each country, but would count the already used emissions from the past as a debit. Meaning that the old industrialized countries would have to go shopping to developing countries for permits (Fig. 5).

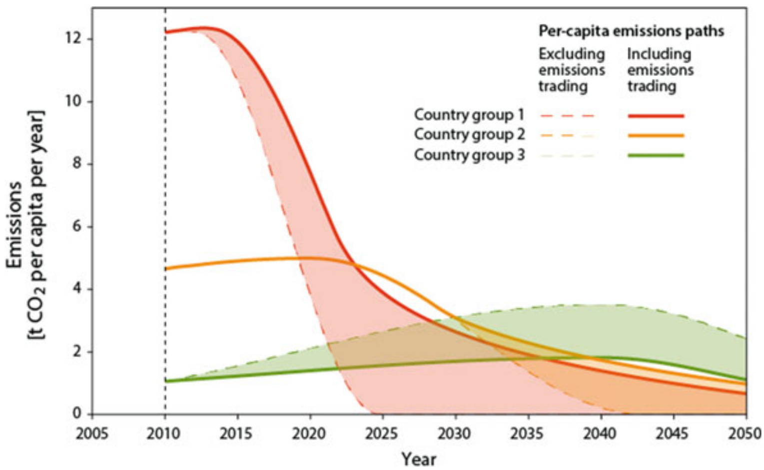

Fig. 5 The "budget approach" rendering each country the same per capita permit of emitting greenhouse gases. But the old industrialized countries (red colour) would soon run out of permits (dotted red line) and would have to go shopping to developing countries (green colour), thus inducing those to accelerate their own decarbonization

This mechanism miraculously would make it lucrative for developing countries to join the North in stabilizing and soon even reducing carbon burning while accelerating the transition to renewable energies and efficiency.

We at the Club of Rome are confident that humanity can and will make use of some of the ideas that allow increased prosperity while stabilizing climate and natural systems.

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The Systemic Risk Perspective: Social Perception of Uncertainty and Tipping Points

Ortwin Renn

Abstract Humankind is confronted with two types of risks: conventional and systemic risks. Conventional risks can be contained in space and time, follow linear cause–effect relationships, and require effective and pointed interventions into the cause–effect chain. Systemic risks, however, are characterized by high complexity, transboundary effects, stochastic relationships, and nonlinear cause–effect patterns with tipping points and often associated with less public attention than they deserve. Systemic risks range from natural hazards, environmental threats, and financial crisis to cybersecurity. Due to their special features, systemic risks are overextending established risk management and creating new, unsolved challenges for policy making in risk governance. Their negative effects are often pervasive, impacting fields beyond the obvious primary areas of harm. The following chapter describes the distinct features of systemic risks and explains their properties. It focuses on the issue of risk perception and the likelihood of insufficient attention by policymakers and the public at large to systemic risks. The main argument is that a graphic representation and simulation of evolving systemic risks and a participatory deliberative approach of inclusive risk governance are needed in order to prevent, mitigate, or control systemic risks.

Keywords Systemic risks · Attenuated risk apprehension · Risk paradox · Stochastic nondeterminism · Inclusive governance · Learning in virtual environments

1 Teaser (In Lieu of an Introduction)

Think of a time period 4,000 or 5,000 years ago. There is a little anecdote, which, of course, is fictitious because nobody was there to observe it at that time. Imagine three cavemen sitting

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in front of the cave, and they are talking with each other about life. The first caveman says, “Look, I think we have a wonderful safe life. If you look outside, we have clean air. There are no pollutants anywhere around, and we are in the fresh air all the time. We are working outside, and it seems to be a very safe environment.” The second caveman replies: “Well, even more so, if you think about our water, it is all clean fresh water. We take it directly from the springs that we have in front of us. All clean and fresh!” The third person enters the conversation: “Well, and our food is all organic. We eat only food that Mother Nature has given us.” They continue to contemplate about their life until, after a while, one is scratching his head and remarks: “Well, there is only one question I have. Why on average are we getting no older than 30 years?”

2 The Increase of Life Expectancy and the Reduction of Accidents

The conditions of human existence in terms of life expectancy and health conditions have improved considerably, specifically in the last 150 years. From 1950 to today, we witnessed another dramatic increase. Life expectancy in Germany has increased over the last 30 years by around 12 years, and German newborns have a life expectancy of around 79 for male and 83 for female individuals [32]. That is unheard of in human history. Comparing with life expectancies over the centuries, but also across different countries, this is a very spectacular accomplishment. We succeeded in making life safer, securer, and much less dangerous than it used to be. In that sense, risk is a paradox. While life has become safer year after year but, as revealed by many surveys, our impression leads us to infer the opposite: most people believe that we face more risks to health and life today than during the previous decades [21: 44f.]. However, using the usual risk indicators in terms of premature death, in terms of health losses, and in terms of accidents and other hazards, there is a huge and very impressive record of success. This success is even more stunning in view of the following fact. If one asks how many Germans will die prematurely, and I will deliberately put “prematurely at the age of 60,” the answer is that from 10,000 people in Germany 9,315 will reach their 60th birthday [21: 51]. That, again, is a very impressive number, and it is something that should not be taken for granted. Let me choose another country as a different example. Zambia, for instance, is an interesting case because no civil war or something comparable has blurred the statistics there. Out of 10,000 Zambians, 4,300 will reach their 60th birthday. More than half of them will die prematurely. Hence, there are dramatic differences between countries. However, in nearly all OECD countries, risks to life and health have been significantly reduced.

When we talk about risks, we tend to forget about these success stories. Take occupational accidents. In 1960, 4,893 work-related fatal accidents occurred in West Germany, not including East Germany. Now including East Germany, the number is down to 420 as of 2018.[1] The number of people that actually die during work has been reduced by almost a factor of 10. This statistic includes also the traffic accidents during work. Great Progress! And again, other countries do not fare so well. In Brazil, for instance, which has three times as many inhabitants as Germany, around 5,000 people are killed annually during work [30], a number that is more than one order of magnitude larger in comparison to Germany. Safety cannot be taken for granted. There are many threshold countries that are in the phase of rapid industrialization and face many more accidents than the OECD countries. Therefore, a very strong impetus is required to assure that these countries achieve the institutional and organizational preconditions for reducing the number of work-related accidents and fatalities.

Another example is the dramatic reduction of fatal car accidents. If one takes the year 1972, Germany experienced close to 22,000 fatal accidents. Nowadays, we are down to 3,059 as of 2019.[2] Furthermore, we now drive around 2.6 times more than in 1972 [14: 106]. If you take the ratio of accidents per kilometre driven by car, the reduction amounts to a factor of 16. These are all dramatic improvements.

These examples all refer to conventional risks, risks that we can regulate within a specific regime that can be contained in time and space and linked to a specific sector, in particular workplace or car accidents, technological incidents, or other safety failures. At least ,the wealthy countries apparently have been successful in developing public regulations and institutions that are reducing the general risk so considerably that they still experience increasing life expectancies from one year to the next. It is a public prejudice that life expectancy is stabilizing or even decreasing. At some point, it will, but not yet. Hence, the perception that life is getting riskier every day does not fit the statistical reality.

3 Systemic Risks and the Risk Paradox

About 78% of the German population believes that life has become riskier over the last two decades [21: 24]. They believe that we face more threats that life has become more dangerous. However, that does not seem to fit the overall epidemiological results derived from reliable data sets by established statistical methods. I have called this discrepancy the risk paradox, but, at the same time, we also witness a phenomenon that we framed as risk attenuation. That leads back to a theoretical concept that Roger Kasperson, Rob Goble, and others including myself have developed in the late 1980s [10, 18, 26]. It claims that risk apprehensions are either amplified through social processing of information, communication, and perception, or they are attenuated.

Either the magnitude and likelihood of a risk might be augmented or amplified, or, reversely, some risks that have the potential to do great harm may appear more or less attenuated. Such seemingly attenuated risks are neither visible in the public

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[1] https://de.statista.com/statistik/daten/studie/276002/umfrage/gemeldete-toedliche-arbeitsunfaelle-in-deutschland-seit-1986/.

[2] https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Verkehrsunfaelle/_inhalt.html.

sphere nor are they often discussed in the public debate. We refer to these risks as systemic risks [22].

Systemic risks have a couple of features that makes them likely to be apprehended as attenuated. But before coming to the features, it is necessary to define systemic risks. Systemic risks have the potential to threaten the functionality of a vital system on which society relies. The services associated with such a system, for example energy supply or internet access, are crucial for people. These risks can still be assessed in terms of lives lost, health impacts, or impediments to wellbeing, but the focus on functionality provides a different perspective on what is at risk here. These risks may pertain to crucial social services in terms of energy, water, health, food security, and education, or to technological services such as the internet or its cybersecurity. They have the potential to endanger or threaten the functionality of those systems or even destroy them in such a way that recovery, at least fast recovery, is not possible [13]. That is the first major aspect of the concept of systemic risk.

The word itself has been used frequently when referring to financial risk. In 2008 and 2009 during the financial crisis, it was called systemic risk because the chain of events acted like domino bricks (see early definition by Kaufman and Scott [11]). If you start with one, then all others are collapsing, and in the end, the whole system loses functionality. We know the financial system was close to collapse. So, when referring to systemic risks, we think of the potential that a crucial system may be threatened by an entire set of potential activities or events that could trigger dysfunctionality or even collapse [9].

4 The Characteristics of Systemic Risks

What is it that makes risks systemic as compared to conventional risks? First of all, these risks are very complex [14]. While "complexity" is a rather fashionable word with frequently unprecise use, the attribute complexity has a clear meaning when describing systemic risks. Here, it does not merely mean that things are complicated but, with regard to the relationship between triggers and consequences, between causes and effects, that there are many variables intervening in the chain of causes and effects making it is either impossible or at least extremely difficult to reconstruct a valid chain of causal structures that allows to discern the triggers, the consequences, and the impacts of these risks. Often, there is only a vague representation of all the relationships and interdependencies.

Complexity means we have a whole web of intervening factors that interact with each other, that reinforce each other, and that attenuate or amplify the given causal relationships. Very often, we can retrospectively understand what has happened. However, we cannot predict what will happen. This gives rise to a large uncertainty, which is a second major characteristic of systemic risks [25]. It is not just that we need to consider the usual statistical confidence intervals. There always are probability distributions with confidence intervals when we reach into the stochastic world. But with systemic risks, we enter the world of genuine uncertainty. In this world, identical causes may lead to different effects in different situations, even if the observer is cognizant about these situations and knows perfectly well in which way they differ. This feature is familiar from health physics such as in case of cancer, for example. We know the overall distribution over time but we cannot say which individual will be affected. Often, we are even uncertain about population risks; in particular if context conditions are changing. This kind of second-order uncertainty is typical for systemic risks.

The third major characteristic of systemic risks, due to their complexity and their uncertainty, is their trespassing of boundaries, national boundaries as well as sectoral boundaries [28]. A good example is the risk of mad cow disease, or more accurately the variant Creutzfeldt–Jakob disease (vCJD; [36]). This is an example of the past, but is mentioned here because the major risk was not the health threat but the risk to the institutions dealing with the threat. In all of Europe, only about 174 additional cases of the Creutzfeldt–Jakob disease occurred, which is not a major threat considering that about 300 million people were exposed, but the event had a lot of repercussions as ministers had to resign and a major economic loss for agricultural products occurred in the UK. Due to the loss of trust, many agencies were remodelled, among them the European, German, and British food protection agencies. Obviously, one type of risk has caused ripple effects from one sector to the next, from the health sector to the economic sector, from the economic sector to the political sector, and from the political sector to the institutional sector. Each time it extended into the next ripple, the perceived risk increased in intensity and impact.

For many of these systemic risks, we do not know what triggers them, and there might be tiny instances that trigger major impacts. That makes it difficult, for example, for regulatory bodies to anticipate them. Conventional risks in comparison are very clear: These are cars at high speed, for instance, which can have accidents. Consequently, we make sure that the cars are getting technologically better and the drivers better trained. In the field of systemic risks, however, there may be impacts from a very different domain that turns over to another domain and create havoc there. Systemic risks transcend boundaries of jurisdiction, nationality, or sectoral responsibility. Consequently, it is extremely difficult to regulate such risks. Global risks, in particular, such as Climate Change or water pollution worldwide or agriculture and nutrition, cannot be confined to one sector, country, or legal domain.

The fourth characteristic which is probably one of the most problematic in terms of human learning refers to nonlinear cause–effect functions with thresholds or tipping points [24]. The tipping point problem is extremely difficult to handle because those, who take risks, get positive feedback for what they are doing until a specific point. As soon as this point is reached, it is too late, however. We have seen this pattern evolve during the financial crisis. Everybody was very confident that they would handle the risks and could go on forever. Anybody in the financial world was very much aware that they should not inflate the virtual assets without having any real value behind them. However, if everybody thinks, “I am out before it collapses,” then the system is bound to collapse. In fact, even those people who felt very confident about being ahead of the financial lottery lost a lot of money. Then in the end, the governments had to bail out the financial sector and put a lot of taxpayers' money into protecting the functionality of the banking system.

If we are confronted with nonlinear systems that have tipping points, we do not get enough feedback to learn when these thresholds have been reached. Once the thresholds have been surpassed, we may experience irreversible effects that will be very difficult to undo. That is a situation to which our learning capacity is not very well prepared for, since we learn by trial and error [34]. However, with such risks, trial and error is not a good strategy. Having reached the specific tipping point, it is too late to learn. Societies need to make changes before negative feedback arrives. That is one of the big challenges of dealing with systemic risks.

To sum it up, systemic risks tend to be transboundary, and they are stochastic in nature which means they do not follow deterministic cause–effect chains. They can occur under specific circumstances, but we do not know exactly what these circumstances are. These risks hide behind positive feedback to our activities for a long time but if we continue to act in the same way, we reach a point of no return. The switch moves from positive to negative feedback almost instantly. Systemic risks are very complex so that we feel overtaxed in understanding these risks. As a consequence of these features, we tend to go into denial. Most systemic risks tend to be apprehended as being attenuated, even if we are fully aware of them, such as Climate Change, for instance [20].

Looking back to the conventional risk, we can learn that awareness is not enough. Significant risk reduction requires also effective governmental regulation together with behavioural changes. If awareness, collective rules/institutions, and behavioural adaptations proceed line in line, one is able to reduce these conventional risks to a point where they are partially marginalized.

Interestingly enough, if we ask people what they are most concerned about, many of these marginal risks are mentioned because we still have cultural memories of all the hazards and perils that endangered our grandmothers and grandfathers, mostly threats that are readily available in our minds [21: 193ff.]. The new type of systemic risks appears to be more distant, but in the end, they are much more dangerous for modern people than the conventional risks that we have largely mastered during the last decades. This is another paradox, not just the paradox between public risk awareness and the results of statistical analysis, but also the paradox that some of the risks that exert a strong impact on the functionality of our systems are likely to be perceived as attenuated in spite of the fact that people perfectly know about their real magnitude [27]. It is not an issue of knowledge. It may be an issue of apprehension to understand the proportionality of these risks compared to conventional risks but the mechanisms of systemic risk are widely known to many institutions and individuals. However, they tend to take them not seriously enough and engage in serious efforts to reduce the risks to a degree that we all would feel comfortable with. The best example of this is Climate Change. Until 2018, we have faced increasing CO_2 emissions year after year (only exception 2009 after the financial crisis). In 2019, this spiral to the worse has stopped, yet it is still too early to claim a break or even a shift in the overall trend. Global CO_2 emissions from coal use declined by almost 200 million tons (Mt), or 1.3%, from 2018 levels, offsetting increases in emissions from oil and natural gas.[3] The overall CO burden remained more or less the same as in 2018.

In spite of all the conferences, summits, and meetings that we have organized on Climate Change, we are not reaching progress here, at least on the global level. Considering renewable energy, one might argue that there is more renewable energy in the world than ever before. This is true, but if we look at the numbers, the increase is far from being impressive. From 7% in 1998, the global harvest of renewable energy has increased to just 11% today.[4] Given all the hype on renewable energy, increasing the share of renewable energy from 7 to 11 percent within 20 years is not dramatic. Compared to the other risks and their reductions which were mentioned in the beginning of this article, i.e., traffic accidents, occupational health and safety, and technical accidents, this increase is comparatively modest, to say the least. Therefore, we need to raise the question: Why are we much more hesitant to reduce these systemic risks than reducing the conventional risks where we experienced a lot of success?

5 Temporal and Spatial Connection—Issues of Risk Perceptions

Why is that that we are not so serious about systemic risks? That question leads to the psychological domain of risk perception. In 2010, more than 67% of the German population expressed concerns about genetically modified food [21: 90]. However, there are hardly any genetically modified organisms for sale in Germany because they are not on the market. Why are people thinking that they are threatened by a risk to which they are not exposed?

I would like to give a little bit of background about the perception of risk, i.e., how people intuitively assess and evaluate risks (more details in: [21: 301ff., 23: 43ff.]. We should first be aware that individuals intuitively associate causation strongly with proximity in time and space. In terms of anthropology, this is very prudent. Normally, if something happens to us, it makes sense to look for causes in the vicinity of where it happened. So, we ask ourselves: what happened just before the event in our vicinity. If I eat something that contains a poisonous chemical, I will experience some health problems within minutes or hours after the consumption. For complex systems, that reasoning does not work. If an expert talks about Climate Change and states that "the exhaust gases of your car may have an impact on a flood in Bangladesh," such

[3] https://www.iea.org/articles/global-co2-emissions-in-2019.

[4] Globally, total renewable energy generation capacity reached 2,351 GW at the end of 2018—around a third of total installed electricity capacity. Hydropower accounts for the largest share with an installed capacity of 1 172 GW—around half of the total. Wind and solar energy account for most of the remainder with capacities of 564 GW and 480 GW, respectively. Other renewables included 121 GW of bioenergy, 13 GW of geothermal energy, and 500 MW of marine energy (tide, wave, and ocean energy). From: https://www.irena.org/newsroom/pressreleases/2019/Apr/Renewable-Energy-Now-Accounts-for-a-Third-of-Global-Power-Capacity.

a statement seems to be far-fetched. It is temporally and spatially not connected to what people experience. There is a very strong doubt that these complex relationships have any plausibility. It is rather clear that many advocates of the populist movements take advantage of the implausibility of complex relationships. They offer simple, seemingly plausible explanations. All kinds of conspiracy theories appear to be much more plausible than the complex web of Climate Change triggers. Denying the threat of Climate Change is fortunately not a powerful movement in all countries, but we can see that specific groups in society do not believe in Climate Change as something that is caused by human action [1]. And they gain momentum because the relationships appear to be so implausible. My little car should have an impact on a natural disaster in East Asia? If you trust scientists or the science behind the claims of Climate Change, trust can overcome counter-intuition, but if you do not trust them, you fall back to intuition. Systemic risks are complex by nature. Their causal structure defies mechanisms of plausibility. That is the first reason for the likelihood of attenuation or even denial when it comes to complex, systemic risks.

6 The Stochastic Nondeterministic World

The second reason for attenuation refers to the experience of stochastic relationships. Specifically, systemic risk can hardly be characterized by deterministic relationships [14]. There are only a few "If A then and only then is B" causal connections between drivers and consequences in the context of systemic risks. The best we can do is to calculate the probability distribution over outcomes when the effects of one driver or several divers are assessed. However, when scientists communicate these stochastic relationships, many people are confused. They think: "Oh, even the scientists do not know for sure. They are also ignorant about this complex issue." Or, even more to the point that I want to make, they say, "if the scientists are not certain, then I can just as well rely on my intuition." Unfortunately, much of this knowledge relativism is allegedly supported by the social science concept of social constructivism, i.e., the belief that all knowledge is a product of social communication and exchange and not of observing external cues from nature or society [6]. The confusion about what truth means and how scientific claims are substantiated has given rise to a sense of insecurity and irritation: "If the scientists do not know for sure, then we are free to take whatever truth claim fits our interest." And soon, society ends up in the post-factual era [15: 128ff.]. People go out there and bluntly lie about factual relationships, because nobody can distinguish anymore what is truth and what is a lie and what is an error. In extreme cases, people take all their prejudices as valid truth claims.

We may complain about this post-factual abuse of truth claims but there is no way back to the conventional scientific concept of determinism [23: 30]. Scientists have learned that there is much more complexity and stochasticity in the world than we had previously assumed. However, I think we have failed to make those new visions of the world become better understood by the public at large. Truth claims from science are far from being arbitrary or representations of wishful thinking; they rather demonstrate the complexity of the phenomena that we want to understand better. They can be characterized and described much more accurately by using stochastic models than by using deterministic relationships.

Furthermore, stochastic modelling is also a reason for people to attenuate the seriousness of a risk. If we do not have certainty that all these bad consequences will happen, we take an optimistic view and assume that they will not happen. If one observes some of the debates on Climate Change in the United States, one will be confronted with a lot of statements saying, "if the scientists are not 100 percent sure about the anthropogenic nature of Climate Change, I do not believe it." In a stochastic world, we will never be 100 percent sure. It is impossible. It is inherently impossible. This basic message is not easy to convey to a society which has been educated to believe in deterministic natural laws. And as pointed out before, this scepticism towards stochastic reasoning leads to attenuation in the apprehension of risks.

The third element lies in trust. I first mentioned the post-intuition world, then the post-truth world, now I turn to the post-trust world. The post-trust world sheds some light on the relationship between science and the wider public [23: 73ff.]. Most of the threats that we envision and that we are facing do not come from our personal experience. Most modern hazards such as ionizing or non-ionizing radiation, the destruction of the ozone layer by FCCs, Climate Changes caused by greenhouse gases, and health threats caused by mixes of chemicals are not seen by our eyes or cannot be realized through our own senses or through our personal experiences. Nobody of us has seen the ozone hole above us; eating something, we do not know whether the beef in the food has prions in it or not, as prions cannot be detected by tasting. This list of examples can be extended almost endlessly. Take the debate about the pesticide glyphosate (Roundup®). Is that carcinogenic or not? Except the toxicologists, nobody has an idea. In that sense, we are all relying on second-hand information. That is something that is psychologically difficult to deal with. If nobody has a proper way of proving who is right or wrong, then we all need to rely on trust. If we lose trust, we go back to intuition. And then we are again in the vicious cycle of what appears plausible. But let us stick to the topic of trust. There are three major routes of how we can resolve the issue of trust [3, 19].

The first route is that someone has confidence in a reference group, say scientists, that they will tell him or her the truth. Under this condition, the individual will adopt whatever they will tell him or her Assuming that, "they know better than me." Interestingly enough, if we look into the statistical evidence, the group of people who are loyal to a reference group is dramatically decreasing [23: 81]. That is true for almost all sectors of society as we can observe from recent voting behaviour in Europe and elsewhere. Established parties that had millions of devoted voters behind them lost almost overnight the support of their followers. The unattached voter is now dominating the political scenery.

The scientists are still belonging to a category of people that receives the best grades on trustworthiness in almost all surveys in Europe, Japan, and the United States [4]. However, if a scientist is not working in a university but in a factory or in a lab for genetically modified organisms, trust declines dramatically [35]. Overall loyalty towards reference groups that used to dominate the trust landscape in Germany and in most OECD countries is declining. So, what do people do when they lost trust in their previously preferred reference groups? Then they have two choices. The first possibility is to say, "I trust nobody." That means that whatever experts or others may say, they are likely to be in error or to be lying. All statements are allegedly driven by interest. In this case, people demand zero risk [23: 81]. Since I do not trust anybody I rather leave everything as it is now. No desire for change or innovation! People in this camp develop and maintain a structural conservative attitude that tends to glorify the past and be sceptical about the future. Again, we can see that populists from the right take advantage of this structural conservatism and promise to bring the golden days back to the people.

Then we have the third route, which is pursued by the majority of people. We call this strategy "vagabond trust". Because people cannot evaluate the validity of arguments, they look for peripheral cues to assign credibility. Take as an example the usual talk shows that are aired on German TV. In most talk shows, there are four participants in addition to the host [23: 73ff.]. One is defending the activity that is planned or given. For example, the use of glyphosate for pesticide control. So, the industry spokesperson is going to say, "Glyphosate is safe and does not cause cancer. We have tested all of this." Then there is the opponent; this might be a spokesperson from Greenpeace saying, "This is the worst thing that we have used on our land. All the bees are killed, and of course, many citizens get cancer." Then the third participant comes from a regulatory agency, in this case, the Federal Institute for Risk Assessment: "It is all a question of dose, and we regulate exposure so that the critical dose is never reached." Then we have a fourth person, normally an actor or an actress representing common sense and usually saying something like, "I did not know that it was all that bad!" This is the typical composition of a host show in Germany. If the audience who watched the TV show is asked after the show about the arguments exchanged by the participants, most people are unable to remember any of these arguments. But they can tell whom they found trustworthy and whom they tend to believe. So, somebody from the audience might say: "I liked the lady from Greenpeace the most. First, she was very alert and attentive. Secondly, she had this elegant form of articulating herself and I appreciated the way that she really had good answers all the time. I do not remember which they were, but they sounded good. I think she is right." People tend to judge the truthfulness of statements by peripheral cues of credibility [2, 16]. That does not mean that it has any real relationship with what scientifically might be true or false but that it is driven by the impression that viewers associate with each participant. Needless to say, that such cues are also connected to the plausibility of what is being said. And again, we are back to the problem of intuition versus complex knowledge.

However, the vagabond trust assignment has another problematic consequence. The first week, the spokesperson from Greenpeace may be the person who gets the most trust credits, but a week later, this might shift towards another participant, maybe the representative from industry or the regulatory agency. Then people reconsider what they thought was right or wrong and might change their judgment. Changing judgements is not pleasant; psychologists call this the pain of cognitive dissonance

[5]. Most people can get very angry if that happens to them and out of frustration and insecurity about what is right and what is wrong, they tend to develop a feeling of anxiety and sometimes aggression.

7 Uncertainty and Insecurity

Thus, people change, they trust first this person and then over next week, the other person and so on. More and more they get nervous about that. They feel increasingly insecure about an issue. Insecurity leads to heightened risk perception. The more people feel insecure about the severity of a risk, the more they will rate such a risk higher than risks that are more familiar to them. Thinking and re-thinking about threats and being torn between competing cues affects risk ratings [8]. You get first annoyed about it, but secondly, in order to get over this cognitive dissonance, you start to see the risk as more pronounced than you would have seen if you had either delegated it, regardless to whom, or if you had factual insight into the argumentation. That has major impacts, for example, on crime. Individuals who have the least experience with crime tend to have the highest anxiety of crime, because they rely on contesting testimonials of crime commentators on TV, other media, or social media [23: 118f.]. The same is true for refugees [31]. In areas with the lowest percentage of refugees, we can observe the highest anxiety with respect to refugees conducting crimes. That is a mechanism of vagabond trust situation in which trust is becoming a currency that is changed and exchanged from time to time, heightens the anxiety and the preoccupation with that specific risk. In the end, it may lead to high attention to some of the rather well-managed conventional risks (that still may raise controversies) and leaves no room for dealing with the complex systemic risks that are less attractive for TV host shows.

8 Cognitive Dissonance in a Post-communication Environment

The last cause of attenuated apprehension of systemic risks is related to the topic of post-communication. It does not mean people have ceased to communicate. They communicate more than ever but in a different form. Now we are in the domain of media communication, specifically of social media [12]. Special attention should be given to virtual spaces in which people exchange their views and ideas. These virtual spaces are optimal opportunities to avoid cognitive dissonance. That is less prevalent in Germany than, for example, in the United States but the appearance of so-called echo chambers is a serious problem [15: 96]. In these echo chambers, people want affirmation of and confirmation for what they already believe. When we engage in physical communication or use conventional media such as newspapers, we are always confronted with judgments and opinions that differ from our own positions. Under these conditions, we are more or less forced to reconsider our own position. Cognitive dissonance is a driver of learning. If individuals avoid cognitive dissonance, first, they do not learn anymore, and secondly, they believe that anybody who shares their opinion is their friend and anybody who disagrees is their enemy, and nothing is in between. This is very prevalent in the social media where users can get really upset if someone says something opposite to what they believe. The structure of social media facilitates this kind of avoidance of cognitive dissonance. It creates polarization [7].

A couple of years ago, we conducted research on two focus groups at the same time and at the same location. One group assembled individuals who strongly believed that an expansion of mobile communication would be dangerous for their health. The second group was convinced that there is a need for more and powerful infrastructure for mobile telephony. The two groups met separately in two different rooms. I was commuting between the two rooms. Then I heard a person from the first group saying: “Well, if you go to Google, you get an immediate proof that magnetic fields are very dangerous for your health.” When I entered the other room, I heard somebody saying “When we go to Google, they say there is no problem.” So, we asked both groups to convene in one room and I took one laptop from each group and asked the owners to type in: “What are the health risks of electromagnetic fields?” The first group started the Google search and got as their first shot a paper entitled “Even cows get cancer from electromagnetic fields.” This was a Bavarian study that was conducted several years ago and reported about cows near transmission lines. The second group entered the same question into the Google search engine. Number one of that search was a paper entitled, “WTO foresees no problem with cancer when expanding networks on electromagnetic fields.”

What happened? Very cleary, both groups had included the learning mode when conducting searches. The first time they consulted Google, they looked for something that confirmed their view, and they did this many times. Over half a year, Google learned what they liked to hear and made sure that the entries with negative comments on mobile telephony were placed among the top 5 of the search list in the first group and, vice versa, that the most positive entries came out top in the second group. Most people do not go further than looking at the first three entries. And those were confirming what in both groups had been believed before already. Since over time the Google search produced more and more confirming statements, the user was left with the impression that slowly but surely the world has learned that he or she was right in the first place. However, this was true for both groups. Having no experience of cognitive dissonance, the only conclusion for both groups was that non-believers are either dumb, bribed, or cynics. If someone is bribed, dumb, or cynical, you do not have to talk to that person anymore. Then communication is considered a waste of time. Polarization will take place and we can see this right now in the United States between the adherents of the two major parties. They do not see any need for further conversation, deliberation, or negotiation. There is only right or wrong, black or white. This tendency is a real danger for democracy.

What does post-communication tell us about systemic risks? These risks cannot be adequately described by polarization in right or wrong. The stochastic nature of the issue, the nonlinear features of the causal effects, and the complex structure require shades of grey between the two extremes of right and wrong. In those countries where polarization has strongly evolved during the last decades, the governance of systemic risks has led to paralysis of the political regulatory system since there is no way to compromise in a polarized world [27]. Climate Change advocates and Climate Change deniers are irreconcilable against each other and make Climate Change an issue of almost religious belief. The new Friday for Future movement also tends to use science as an ultimate stronghold against the inactivity of politics and economics. Those who believe in Climate Change blame others for not doing anything, while those who do not believe have no reasons to adjust. Non-action is the consequence. Again, the risk apprehension tends to be attenuated rather than amplified even if verbally the fight for Climate Change protection has increased in intensity.

9 What Have We Learned About Systemic Risks: A Summary

Now given these effects, let me conclude in few words what I have tried to point out in this article: First, it is helpful for the discussion on risk governance and risk management to distinguish between conventional and systemic risks. Conventional risk can be contained in time and space, is fairly easy to assess by using scientific methods, and can be managed by introducing effective interventions at the right places in the known cause–effect chain. So far, we have been extremely successful in dealing with conventional risks in most of the OECD countries (the picture is quite different in many threshold and developing countries). The conventional risks need to be distinguished from systemic risks. These are characterized by complex relationships within the cause–effect chain as well as in their interaction with external systems. They follow stochastic reflationary patterns, they include sudden tipping points, and tend to transcend traditional geographic, political, or sectoral boundaries. In this field of risk, all our management and governance approaches are less successful. It is also less obvious of what science can do to assist risk managers and policymakers in reducing systemic risks. One major obstacle for bridging the gap between the acknowledgment of systemic risk as a serious challenge and the lack of effective actions that are required to deal with these risks effectively is the likelihood of attenuated risk apprehension in the public discourse. This is due to specific heuristics of how most people perceive these risks.

In this article, I identified four major reasons that may trigger the likelihood of attenuation. The first reason is that most complex systemic risks run counter to our intuition that serious dangers are caused by factors close in space and time. Anything that appears “far-fetched” is also seen as less plausible and less obvious than risks whose driver we can immediately observe in our own neighbourhood. Secondly, science cannot provide deterministic and non-ambiguous models of systemic risks. Although they are far from being arbitrary, people tend to withdraw trust and credibility to information that is associated with uncertainty and ambiguity. Public perception often oscillates between the belief in determinism on one hand side, which is scientifically problematic, and arbitrariness on the other hand, which is far away from what science can indeed offer.The third reason refers to the need to trust in scientific assessments even if they are not plausible, visible, or reconfirmed by personal experience. To rely on information that only others can provide and that we cannot prove right or wrong creates a lot of tension. Distrust in science is still not wide-spread but clearly increasing. Furthermore, as soon as scientific dissent is openly recognized, most people refer to so-called peripheral cues to assign trustworthiness or credibility. Since these cues change over time and are often contradictory, people feel irritated and frustrated and usually prefer inaction rather than risking to do the wrong or the inappropriate thing. Fourth, confusion is all reinforced by new communication tools in the IT world, in which everything that we believe, every prejudice we have, finds support in the social media and assembles enough followers to confirm whatever we believe is true. As a consequence, knowledge camps become polarized and differentiated approaches that are crucial for dealing with systemic risks become marginalized.

10 What Can We Do?

Last not least, I want to address the question: What can scientists and science institutions do to deal with systemic risks and their attenuation in public perception? As I pointed out, our usual learning mode of trial and error is totally inapt to deal with nonlinear cause–effect chains with sudden tipping points. However, trial and error as a heuristic is deeply engrained in our learning process [34]. So, we need to create a virtual environment in which we can simulate trial and error. If the virtual error occurs, people can experience what it means to trespass these tipping points. Fortunately, these negative experiences then are only simulations and not real events. But they can sensitize people not to wait for negative feedback before changing behaviour and lifestyles. This method of virtual preparation for relying on anticipation rather than trial and error is effective only when the simulations are framed in a form of a plausible, easy-to-grasp, and credible narrative. It has to be so convincing that people conclude, "Oh, if that is really happening, I better change now before this kind of disaster is approaching." The simulations need to be not only scientifically well designed. They also need to be so well visualized that people feel as if they were real. This task is not trivial and requires a joint effort of excellent modellers, natural scientists, social scientists, communication specialists, and psychologists. It may even be wise to include professional writers and science fiction authors.

Beyond encouraging anticipation, it is crucial to include people more into collective decision-making. Once they get engaged in making decisions collectively for their community, they are much more willing and determined to learn about the complexities in which they operate [33]. If they sit around a regular table in a pub, they will not care much about facts and complexities, they know what is right for the world, and nobody can make them change their opinion. However, they are invited to join a Round Table with other citizens, the situation transforms dramatically. People become aware that their opinion and their judgment will have an impact on the well-being of the community in which they live. They feel more accountable for all the preferences that they articulate [23: 165]. We have accumulated good evidence that people in situation of collective decision-making are, first, more willing to look into more complex relationships and deal prudently with uncertainties and ambiguities. Secondly, they are willing to resolve conflict by looking into the trade-offs between different options and consider not only the consequences for themselves but also for others who ideally are all represented at the Round Table. For this to happen, we need excellent opportunities and open spaces that provide such a catalytic service to the communities. Social scientists are capable to investigate and design the appropriate institutional structures and processes in which people are encouraged to develop these civic virtues of evidence-informed and value-based production of collective decision-making.

The last point that I like to raise may be more contested than the two that I just elaborated on. The recent development in the sociology of science and knowledge towards a postmodern understanding of science as one narrative among others provides a disservice to society in my eyes [15: 123]. My main argument is that all our efforts to explicitly mention and characterize uncertainty, to stress the stochastic nature of what we know, and to point out the various ambiguities in the interpretation of complex relationships help society to get a more accurate and more truthful representation to what we frame as reality than gut feelings or intuition. We should make it very clear that through sciences we are able to set boundaries of legitimate knowledge [29]. To step outside of these boundaries means that we accept knowledge claims that are either absurd, without any evidence or mere wishful thinking. That is where scientists are really needed because normal intuition is not a good guide for inferences about complex systems. Scientists should be encouraged to make these boundaries more visible and pronounced in public discourse. "Anything goes" is not an adequate response to complex challenges and even less so to deal with complex risks. True is also: To resolve complex problems, we cannot rely *only* on systematic scientific knowledge, we also need experiential or tacit knowledge but without scientific knowledge and its rigorous methodological approach, we are likely to fall prey to "comfortable" illusions or manifestations of special interests and value camps. We need science as a watchdog about what we really know about a phenomenon and the relationships between phenomena. Only on that premise can science meet its role as an honest broker in societal discourse [17]. If we talk about complex systems and their impacts, nothing is better than a very good, rigorous scientific analysis. We should be proud of what science has been and still can offer to society. Science is not the only actor but an indispensable actor when it comes to the identification, analysis, and governance of systemic risks.

The recent development in the sociology of science towards a postmodern understanding of science as one narrative among others provides a disservice to society.

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On Ecological Ethics

Patrick Dewilde

Abstract The topic of this chapter is how Ethics and Earth Ecology relate to each other. Given the dynamics of the Earth's ecological system, ethics takes the meaning of an emergent layer of quality control on human's actions in the organic global Earth environment. Fittingly, the paper starts out with a brief account of how System Dynamics characterizes the behavior of complex large-scale systems and how the characterization applies to the Earth's biosphere. *Chaos* and subsequent *emergence* play a central role in this characterization. They provide the scene on which human behavior has to evolve, using, in particular, intelligence as the ability to imagine, estimate, plan, influence, and to some extent control the Earth's development. The human interaction with the Earth's ecological system obviously needs direction toward insuring sustainability of its actions, and preferably even generating a high global quality (QoL) of the symbiosis of humans with their environment. The paper, therefore, develops a theory of ecological ethics based on insights from medical ethics and the striving toward achieving individual human health. This approach leads to the identification of classes of "diseases of ethics" and their incidence on Earth's global health. It motivates the unequivocal choice for a new type of humanism extended to the Earth's global ecology, as the basis for this "emerging" ethics. The paper then ends with applying these ideas specifically to the future organization of economics in a healthy, sustainable way, and the discussion of potential measures to achieve this.

Keywords Ethics · Ecology · Emergence · System dynamics · Quality of life · Health

1 Introduction

In the Iliad, Homeros shows how wrath and vengeance leads to the destruction not only of enemies, but of the protagonists themselves, in this case Achilles and

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Agamemnon. Wrath benefits nobody, nor does vengeance create justice: they mainly destroy people and their values. Homeros makes thereby a strong case of political ethics, some 900 years BC. According to Socrates, ethics is *the formulation of an answer to the question "what is a good life?", where "good" is to be understood in the ancient Greek sense as "true to nature"* [21]. In our last and present centuries, we are faced with the very pertinent question of "what would be a *good* Anthropocene?", or more precisely, "what does it mean for humanity to behave in a *good way* with respect to their habitat, the Earth?". An answer to this question hinges on the meaning given to the word "good" in the global context of the Earth's system *including humanity and its actions*. This will be the goal of the present chapter: the development of what may be called ecological ethics. At a first glance, it might seem difficult to approach the ill-defined and abstract term "good" in a systematic way, but that is precisely the task ethics is facing, necessarily based on present-day understanding of the dynamics underlying the evolution of our Earth's system, and the role "goodness" plays as a common term in societal, medical, and engineering practice. Any sensible ecological ethics has to recognize that the Earth and its biosphere (including humans) form one highly integrated organism in need of continuously fostered health [19]. Effective health of an organism requires at least sustainability, but needs the fostering of a high *Quality of Live (QoL)* in addition. This is as in medicine: it is not enough to keep the patient alive! If we, humans, want to give meaning to Aocrates' call for "goodness," QoL is what we have to aim at. This endeavor leads to a pretty precise theory of ecological ethics, very much applicable to the present situation, and in particular to attractive new forms of economic practice that foster ecological health by sustainability and QoL.

2 System Dynamics

The place to start is an up-to-date understanding of system dynamics as it applies to a large ecological system like Earth's biosphere. The ecological system of our Earth shows some pertinent global characteristics: it is extremely complex, with an almost infinite number of state variables, and billions of different types of interactions between them—so it would seem impossible of ever describing it in a comprehensive way! Nonetheless, and of course given the limits of human understanding, system Earth has recognizable and important global behavioral characteristics. *Behavior* is: how the system's evolution appears to outside observers, making abstraction from its detailed internal laws.[1] In this paper, I highlight in some detail two of the main

[1] The "behavioral" point of view is typically the level at which understanding can be achieved between a lay person, who only knows about appearances, and a specialist, who knows about internals. For example, the depletion of the ozone layer has produced effects that can be experienced by

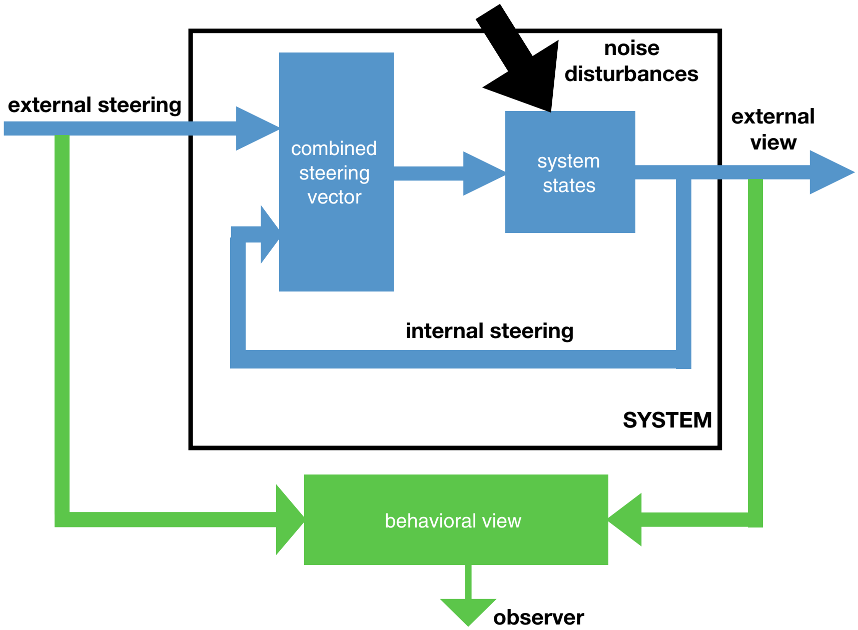

Fig. 1 Schematic model of a dynamical system. The heart of the system are the state variables, which evolve dynamically, steered by a variety of influences, both external and internal (in the Newtonian model, the steering consists of forces that influence the derivatives of the quantities characterizing the state). The *behavioral view* observes both the states and the external influences and deduces from it its (necessarily colored) view on the system. The arrows in the diagram indicate information flow: from information source to user. An ecological model of the earth will have a great variety of types of states: positions, velocities, pressures, temperatures, chemical concentrations, etc...

properties of (non-linear) large-scale dynamic systems in general and our global Earth system in particular: *chaos* and *emergence*. It is important to understand what these notions mean precisely and how they affect the system's dynamics. We shall see that the two are intimately related like opposite sites of the same coin.

The first characteristic of large-scale, non-linear, and highly distributed systems like most biological and natural systems is the incidence of *chaos* and *emergence* [16]. By definition, *chaos is extreme sensitivity to "initial" conditions, i.e., to the*

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anybody, while the mechanisms involved require specialized knowledge of chemistry. The potential lack of understanding between lay observers and scientists is a major obstacle to sensible ecological policies. It can only be bridged by what I call *semantic alignment*, i.e., agreeing on how effects can be understood from their outside appearance, without knowledge of the underlying mechanisms.

state of the system existing at the moment when one starts observing (see explanation in Fig. 1).

High sensitivity means: given the state at some specific time, the further evolution from that state on is potentially very different from what it would be when started from a slightly different state (for example, most people living in Europe nowadays are genetically connected to Charles the Great, and would not exist if Pepin the Short had not met Bertrada of Laon—and the same can be said of many other couples living at that time). This effect, ubiquitous in large non-linear systems, has been inaccurately characterized as the "butterfly effect."[2] There are a number of mechanisms that produce chaos. Let me just mention "arrival times" (many evolutions are dependent on some events happening more or less at the same time and same place, e.g., your parents having accidentally met somewhere, or some signals coinciding in your brain at the site of a specific neuron), and "bifurcations" due to "saddle points" (as is the famous symmetry breaking in fundamental physics or the propagation of neural signals, also a ubiquitous phenomenon in biology).

Reasons for chaos to occur systematically are manifold: non-linearities, in particular, saturation effects, combined with instability forced by fluctuations, near simultaneities of influences between autonomous agents (e.g., cells in the brain, humans meeting each other, cells acting on each other), and the ubiquitous occurrence of noise in any system, due to many unrelated events influencing each other in tiny ways. Already ubiquitous noise will insure that no state in the system is precisely defined, and close-by states will lead to very different evolutions thanks to high sensitivity. A large-scale highly distributed system, like the Earth's ecology, the mammal brain, or human society, cannot be described by classical dynamics based on just a few state variables and a stable predictable environment.

As a consequence and given some state the world[3] is in, it appears that billions of billions different new worlds can potentially arise at any moment, while only one becomes our actual world, although those billion++ others are all equally likely. Chaos allows all free dimensions (and there are billions++ of them) to exercise their freedom at any given moment and steer the system in unpredictable directions. It also means that causality completely evaporates: there is no such thing as the "necessary

[2] A butterfly beats its wings somewhere on a Pacific Island, producing a cyclone a couple of months later. It may be true that if that butterfly had not beaten its wings, the cyclone would not have arisen in the same way, but the same can be said from an almost infinite number of possible parallel "causes" (like other butterflies). The cyclone can be influenced by myriad "causes" like wind directions, clouds, temperature differences, etc.

[3] In system theory, a *world* is defined as the global object of study. In our case, it is the Earth as a global ecological system. However, due to the intrinsic limitations of the possibility of analysis, the whole Earth cannot remotely be captured in its full complexity. Every study will be limited to a schematic view on it, based on a limited number of assumptions and focusing only on certain, mostly "emergent" aspects.

causality" of classical (or even modern) philosophy.[4] The world gets recreated at every moment in one of myriad possible directions thanks to ubiquitous chaos.

Where then does the apparent stability of the world come from (apparent because we survive in it, at least temporarily)? The explanation may seem counter-intuitive, but there is an equally ubiquitous complementary phenomenon responsible for the perceived stability, intrinsic in chaotic systems, namely, what is called *emergence* or *emergent behavior*—a terminology that, although quite common, may be criticized, and therefore requires careful definition. *Emergence* is defined as *properties or laws of the system that are not derivable from its structural dynamics, but exercise a controlling influence on its global evolution*.[5]

Although emergence is the normal mode of world's functioning, the notion seems difficult to understand, because we are used to take for determining what we discover as "basic laws" of physics, chemistry, biology, or economics. Those are what we believe define "reality." The fundamental flaw of our reasoning is: it is not because "reality" (only accessible through what we are able to observe) behaves according to a law we constructed that the laws we are able to discover define nature's total reality. The "laws we construct" only produce models for the specific situations, properties, and variables we are able to experience consistently. Most of our observations involve either very detailed, localized, and microscopic effects, or a limited number of emergent and stable globalized quantities. Most happenings in nature could never have been predicted with any precision (such as the arising of a specific novel species).

Emergence is best approached and understood via examples and description of effects. I mention three important and related ones:

– Darwin's "natural selection": *natural selection of a species happens due to adaptivity to external circumstances*. Natural selection has been dubiously characterized as "survival of the fittest," better would be to call it "survival of the best adapted to its environment", although this last formulation also has its weakness, since the organism in question adaptively changes that environment as well, sometimes dramatically—so a better expression would be "the most resilient." Species originate in a chaotic fashion, their survival is characterized by their adaptivity to

4 It is remarkable that many modern scientists and philosophers believe in generalized causality and evolution being deterministic because basic physical laws appear deterministic. This turns out to be a serious systemic—and scientific—error: these natural laws are deterministic only if infinite precision in space and time were possible. It also amounts to a logical mistake: it is not because causality can be observed in a number of cases that all dynamic evolution is necessarily causal.

5 Perhaps not on the detailed local evolution of its constituents, which can often not even be assessed. For example, in a kettle of boiling water the tracks of individual molecules of water appear fully random, although one knows that after a while every molecule has disappeared in the atmosphere. Similarly with the fate of individual atoms or molecules in a human body, although the constituency of specific organs will be pretty stable over a relatively large time.

circumstances independent of their creation mechanism and is hence emergent (as was very patently observed by Darwin in his *On the Origin of Species* [3]);

– in a totally different direction: *semantics* or the ability to attach "meaning" to phenomena, e.g., a meaning to a sound (and this in many layers of understanding): *sounds, words, sentences, and formulas do not contain meaning by themselves*. The act of giving meaning is emergent with respect to the physical means used. The human ability to use natural phenomena for its own purposes leads to "ideological control" on the environment and is hence fully emergent with respect to it. For example, the way we use animals for our own benefit has nothing to do with the natural evolution of these species. However, this type of semantic emergence is not limited to humans and is effectively used by any system that possesses sensors and is capable to interpret the result by actuating self-serving control on its environment. The faculty of sensing and controlling can be found even in very primitive organisms, which over paleontological times succeeded in reorganizing the biosphere, testimony of which is the large geological layers of bio-generated material (e.g., limestone or carbon layers);
– most control on the evolution of a dynamical system is due to an *outside*, interpreting agent. The brain (human or the brain of other mammals) constructs models of what it considers "reality" and then uses these conceptual models to make predictions, devise strategies, etc. to control its environment for what it perceives as benefit. All this control is, of course, emergent and requires an external, analyzing agent capable of actuating its conclusions and decisions (often via proxies, see further for this).

Once understood, emergence is seen to be ubiquitous and an essential ingredient of nature, if not the most important driving force of the dynamic evolution of the biosphere of system Earth. However, to be effective, any emergent agent needs structural steering methods of its own, and hence becomes a dynamic system in its own right, in which novel, again emergent, laws appear that steer its own dynamic evolution. For example, the evolution of a bacterium is determined by certain interactions with its environment: how it feeds itself, how it keeps its homeostasis, how it reproduces, etc. These laws will most likely produce chaos in turn, which provokes emergent control at a next level, like triggering a latent defense mechanism in the affected organ—effectively generating second, third, and further orders of emergence with respect to the original (see Fig. 2). And the hierarchy of emergence will tend to produce ever higher levels of control, as is testified by the cultural history of humanity.

The global occurrence of emergence has enormous consequences for the overall dynamics of what turns out to be a multilayered system of emergences like our Earth's biosphere. Each emergent layer has its own type of states and develops its own dynamics according to whatever possibilities it has, thereby using what lower layers, which they perceive as their "environment," offer. In turn, each layer is being controlled by "higher" layers that use or misuse the possibilities of the lower

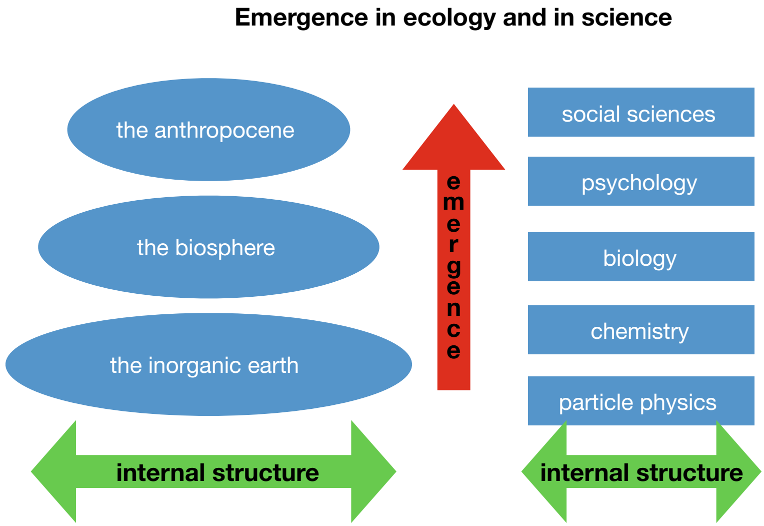

Fig. 2 Two relevant examples of emergence: in earth's ecology and in science. Each of these emergent layers can be decomposed further in sub-layers with their own internal structure and emergent connections. Emergence produces a semantic relationship between the layers, whereby effects of one layer are interpreted by a layer that uses the effect for its own benefit. E.g., humans use sound to communicate ideas

layer. Ecology describes how emergent layers compromise with each other to the benefit of their joint system. A *symbiosis* is necessary for the ultimate survival of the participating species. Ecology happens in a natural way by trial-and-error and natural selection, but can also be steered by intelligence, as explained further. Species that arise, thanks to their ability to organize their life in their direct environment, may disappear when their adaptation starts failing in a larger context. Reasons for this may be depletion of resources, overwhelming or competition by other species, climate change, destructive habits of the very species concerned, poisons, what have you.

The ability of a species to keep adapting to changing environments has been called *resilience* [18]. This notion is akin to the very notion of existence, as "existence as a species" is contingent on the ability to maintain the emergent characteristics of that species. In the case of the general Earth's ecology, the issue would be the continued existence of the human species in the Earth's environment, even though that very species is destroying many of its most vital, life-supporting features.

A dramatic mechanism of creation of an emergent realm is called a *tipping point*. A tipping point [6] occurs when an original small fluctuation gets massively amplified quickly.[6] The tipping point creates an emergence when it succeeds in establishing

[6] Fast relative to the underlying processes.

a novel phenomenon as a recurrent feature, so that, almost all of a sudden, a new order appears out of the blue. Very often, the emergence is due to *reproduction*, i.e., to the ability of the phenomenon to generate copies of itself exponentially, as happens in cell division, in meiosis, or through the propagation of memes, i.e., pieces of information that are understood and communicated further. Due to its almost unlimited reproducibility, the novel phenomenon forces a reorganization of that portion of nature in which it is active, because all the individual "copies" it produces act as a new type of agent interacting with each other and their environment in novel ways. The link with semantics and control should be clear: the tipping point forces a dramatic, unexpected but also recognizable structural change. This kind of emergence is responsible for most of what we are able to recognize as identifiable structure in our biological and even physical world.[7]

Much of living beings (humans, trees) originate out of a tipping point when male gametes meet female gametes (this is one level of emergence), but the way this emergence is established is specific for each species and determines the characteristics of the species (a next level of emergence), etc. It is not hard to understand tipping points when you discover a family of bed bugs under your mattress (and the chaos that produced it)!

Tipping points and emergence perpetually create new worlds, new "universes" with a new order utilizing the existing structures. The new emergent world that so arises is, in turn, subject to chaotic developments itself (unless the phenomenon destroys itself exponentially, what also happens, and the species disappears). In traditional reasoning, the emergence and further development of the new world it creates have been modeled by cyclic processes, like the Schumpeter model [15], with a "fore loop" of growth and consolidation (r-Phase and K-Phase) and a "back loop" of disintegration and reorganization (Ω-phase and α-phase), but cyclic models represent only one level of emergence, while the crux of the game is the evolution from one unpredictable emergence to the next.

While fast growth and final disintegration is to be found in many emergent processes, the Schumpeter model is just too simple to be generally valid and it does not render the ecological situation well, except in specific cases where only a few parameters appear relevant. Proponents of the Schumpeter model claim that in most cases only a few parameters dominate and are therefore relevant [18]. What is actually true is the opposite: the Schumpeter model only applies in low-dimensional cases, and does not apply when the condition on a limited number of relevant parameters is not satisfied. In complex systems, the Schumpeter condition is rarely if ever satisfied. What will derail an emergent phenomenon will likely be another emergent

[7] The relation between chaos and emergence may be difficult to understand, but the notions are two sides of the same coin. An organism will only then be relatively successful if (1) it reproduces exponentially (a chaotic effect), but, on the other hand, (2) it reproduces itself as an ordered organism (otherwise it would not be recognizable: an emergent effect).

phenomenon. Every so-called "equilibrium" or homeostasis will eventually slide into the abyss of unforeseen dimensions.[8] The Schumpeter model can be improved by considering the simultaneity of many cycles that encroach on one another, often with very different time scales. Such co-existing cycles can destroy one another in many different ways, by disintegration, merging, splitting, re-grouping, etc. The history of world politics can serve as a good example, but the origin of species and their evolution is perhaps a better one: species do not move in cycles, either they succeed in preserving their identity by continuously adapting and keeping in balance with their environment (i.e., by resilience) or they appear unable to sustain their needs in that permanently changing environment, where the change is often due to their own behavior. In the latter case, they disappear, mostly by relinquishing their assets to other, more resilient species, which, in turn, may be threatened by ill-adaptation.

Chaos makes creation possible, emergence in its many aspects turns creation into "existence"—that is: what can be observed, because of recurrence and consistency. This, however, is in turn a highly chaotic process, which is itself subject to continuous dynamic evolution. There is no general predictive causality in global evolutionary processes. A priori or predictive causality is a limited phenomenon restricted to specific circumstances and with a relatively narrow time horizon. However, the recognition of evident structure in the world allows for *a posteriori causality*. A posteriori causality is not forward predictive but backward deductive. It explains events by finding conditions that must be satisfied for the tipping point to happen, leaving the actual happening to chance.[9] For example, a woman meeting a man may or may not produce a child, but a child is the result of a woman meeting a man (in some way, perhaps via IVF).

An emergent system needs control on its environment to keep existing and hence power. From our present insights, we know of two main types of control: immediate or natural control (like natural selection or like most instinctive control in the various organs of our body), and intelligent control, which is "model based" thanks to the models our intelligence is able to construct for what it sees as existence, reality, or nature. Intelligent control on a system typically uses *proxies* for control: it does not act directly but utilizes a borrowed power agent and deviates the action of that agent into a different direction forced by the emergent system, like a mahout using the power of an elephant to lift a trunk, or a car driver using a steering wheel to make a turn (in other words, an emergent layer uses power unwittingly provided by a lower layer). All power may lead to violence, i.e., excessive ill-directed force, in

[8] Often a "bowl model" is used to explain the evolution from one equilibrium to another, with a "tipping point" seen as the crossing of the boundary of the bowl. In one or two dimensions, this is an appealing model. It is very unlikely to be valid when many more dimensions and generalized chaos is the case, except for phenomena where the few-dimension model is indeed credible, which are exactly the situations the proponents of the bowl model use to prove their case.

[9] In logic parlance, it determines necessary, not sufficient conditions. In a large distributed system, many more parameters are influential than those one is able to account for.

turn requiring control at a new level to check the violent controller. The relation of control versus power is a very important ingredient of behavior that we shall consider in the (next) section on ethics.

Achieving *resilience*, namely, adaptivity to changing environmental circumstances and the ability to overcome potential threats by natural phenomena, competitors, or even one's own deleterious actions, is a central characteristic of a successful species. But there is more. Resilience is necessary for survival, but it is a defensive property. A pro-active attitude or, if you want, an offensive behavior is often how a successful species deals with its environment. Pro-active behavior can have many forms. It can aim at preventing threatening emergent phenomena, much like the defensive features of our immune system (try to) prevent infections and even cancer (both being examples of emergences in our body environment). The resilience of our body is due in a large part to our immune system, and is certainly necessary for survival, but there is much more: what we use our body for, namely, our goals in life, is at least equally important, because they provide motivation and gumption. This ranges from keeping our body healthy to creating "value" for ourselves and our environment, i.e., our ethics. Offensive and defensive behaviors have to be evaluated in function of their effects on the total environment, in particular, other members of the own species, other species, and our general surrounding ecology. This is what *ecological ethics* amounts to. It will be the topic of the next section.

In conclusion of our brief treatment of system dynamics, it should appear that any ecological action or attitude will only be effective if it immerses itself in the total environment and becomes an integrative part of the Earth's ecological process. From experience, we know that emergent agents may control their environment even so far as destroying it altogether and destroying themselves in the process as well. To avoid this to happen, emergent agents have to intimately mesh their methods with the "natural" proceedings of the overall system, understand them, respect them, let the combined system flourish, and accomplish their goals in a permanently evolving *mutual self-realization*. This process will never converge or become static (stable), but will have to move at each juncture into new forms of dynamic sustainability, adapting to change caused by competing emergences, and this often by creating new emergences of its own. This is the challenge humanity must meet in its relation to the Earth: *we belong to the Earth at least as much as the Earth belongs to us; we should act with nature and not against nature*.

3 Ecological Ethics

Succinctly, the ecology-ethical question for humanity is: *what is a good design of our actions as members of the Earth systems' ecology, given the Earth's natural dynamics, the incidence, and the possibilities of human control on it?* Ecological

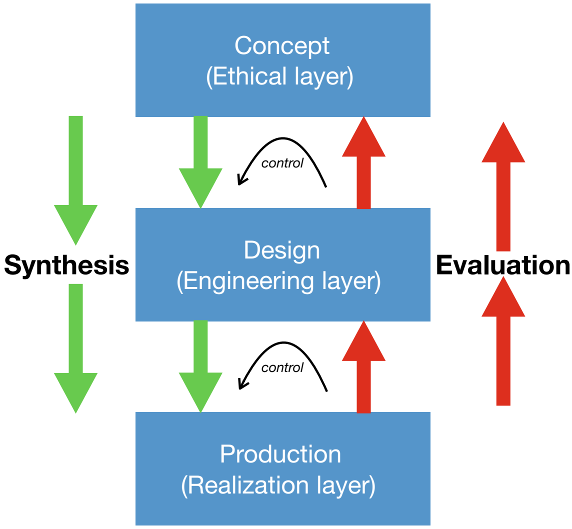

Fig. 3 Emergent control layers in design engineering (a rough sketch: the layers decompose further in a stack of organized sub-layers). Arrows indicate information or control flow

ethics is about defining and implementing quality in the way humanity influences the evolution of the Earth.

The method to deal with *ethics* I adopt and propose in this paper has three sources of inspiration:

- The Socratic ethical question *what is a good life?*—in the present case: *what is a good Anthropocene?* "Good" to be made concrete and explicit as a quality criterion for our behavior as part of the Earth's ecological system.
- The definition of ethics as *the choices a person (or a society) makes to guide their behavior*, following the considerations on ethics by the late Bernard Williams, Professor of Ethics at Oxford University [21].
- The *methodology* engineers use to design a good product, and what the notion "good" means in that context: what is "quality" and how can it be realized?—see Fig. 3.

Notice that "no ethics" or "no quality control" is paradoxically a form of control as well: you just leave things to natural selection and do whatever you wish. It is not hard to guess what natural selection is going to do with our present treatment of nature. Inaction is no option, since action is a central characteristic of life. But we should realize that whatever we do, we shall be subjected to nature's effective criticism and, in particular, natural selection, so we better take the control exercised by nature into account when devising our actions, knowing that all have ecological effects. Nature is at the same time a benevolent and a severe master. Nature gives us many goods and opportunities. When it punishes our inconsiderate actions, the punishment will be the result of our own ill-advised behavior, so we better get serious and develop the necessary ethics as quality control on what we do. We have no choice in this matter. We do not have to be romantic about nature. To take proper care of the Earth's ecological future is a matter of survival as a species, even in a relatively short term, like a few generations.

The connection between sustainability, natural selection, and ethics provides for a powerful criterium to assess the quality of the ethics one may try to develop.[10] Therefore "Ecological Ethics" can best be characterized as how an agent (be it a person, a society, a government) deals with the *health* of the Earth system seen as a global organism, both in the basic sense of sustainability (health and sustainability go together almost pleonastically), *and* in the sense of the *intrinsic quality* of the chosen options—that is: whether these options make the chosen evolutionary course "better" than other choices (here the definition of quality, i.e., what is "better," comes into play.). A potentially disturbing factor is that there is no single notion of "best" or "better," as these notions originate in the ethical process itself. This is like in engineering: quality is measured by criteria such as performance, so a major issue is the definition of performance in the light of ecological necessities of the Earth's healthy evolution.[11]

The health analogy (or paradigm) allows for the definition of what may be considered "ethical illnesses." These are behaviors that do not meet criteria of good quality structurally. Following the analogy with personal health, here are, in my view, the main types of ethical illnesses, which should be avoided or cured as they lead to unsustainability:

- sickness of goals (teleological diseases), when set goals do not aim at quality improvement but at achieving a devious effect (for example, profit optimization, economic dominance, or maximal growth [14], power as a goal instead of a means);
- sickness of means (functional diseases), when the means used are demonstrably contradictory to the aims (e.g., misguided practices, which cause unintended and perhaps fatal harm. For example, the use of most chemical pesticides or the seeding of the atmosphere with harmful chemicals in order to create clouds, the use of disposable plastic bags to improve food hygiene);
- structural incompatibilities (faulty structural arrangements), when the various means used do not harmonize (one effect can be good for the atmosphere while

[10] Quality evaluation of an ethical system is a kind of "ethics of ethics," as it is an effort to evaluate various ways to realize quality, including actual behavior. In the design world, it consists in evaluating the quality rules and practices of a company, while the actual ethics is whatever designers practice.

[11] Some people measure the performance of a car in terms of acceleration, reliability, or even just economy. Present-day measures of performance require the gauging of the car's environmental impact, an issue one would not even have thought of 60 years ago!

detrimental for species diversity, and vice versa, unconsiderate exploitation of human or physical resources, massive soya production for biofuel);
- semantic incompatibilities (lack of mutual understanding) lead to contradictory behavior and cooperating parties not capable of aligning their semantics (for example, partial optimization leading to a best solution at one level incompatible with another, inadequate assignment of responsibilities, faulty interpretation of scientific results, miscommunication, or even deceit).

Examples can be mixtures of the four categories mentioned.[12] One may wonder whether such a classification is necessary and/or useful. I claim that it produces a systematic way to motivate a judgment on the desirability and adequacy of proposed ecological decisions and actions. It provides a method for assessing "meta-ethics", i.e., comparing the quality obtained by one system against another or against common practice.

Ecological ethics as the top "quality control layer" on Earth system management is a new, emergent evolutionary layer needed to insure the future health of our planet. As any system aiming at guaranteeing or improving health, Earth ecology is again subject to evolution itself, dependent, in particular, on increasing knowledge (science) and technology (engineering abilities). For every new technology, there will have to be new ethics, which, again, has to be evaluated for ecological health (effects and consequences). Conversely, every new ethical endeavor will need the necessary means, i.e., power and technology, to achieve its purposes. This dialectical process is never to end and will need permanent societal, managerial, political, and economic support.

As ethical basis for a healthy ecological development of the biosphere-cum-Anthropocene, I want to argue next that an *integrative humanistic* program[13] is the only option capable of achieving sustainable quality, requiring basic respect for all humans to be extended to respect for the total ecological environment, in recognition of the organic integrity of the Earth.[14] The striving toward best quality for the overall ecological health cannot be discriminatory with respect to its living recipients. All humans must be allowed to participate in it, as well as the whole Earthly environment, all species and all natural resources, understanding and respecting their participation

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[12] These categories are based on the recognition of two main logical types of classification, namely, structure versus semantics (or equivalently, aggregation versus generalization) and internal dynamics versus (emergent) control. Each of these carries its own type of disease.

[13] *Humanism* to be understood generically as an ethics based on the respect of the individual value of each human being extended here to respect for the value of the total Earth as an integrated organism, and not as a desire of humans to be "God" as incorrectly defined by some authors. Most, if not all, major religions in the world are profoundly humanistic, although the term has been misused to oppose religion, which certainly is a historical error, since the term is rooted in ancient religious thinking and the revival of the notion in the Renaissance. See also the Catholic stance in the Encyclical *Laudato si*.

[14] Globalization is not a choice, it is reality. Nature is global.

in the healthy functioning of our whole Earth. This also means disallowing unhealthy behavior, based on the best of our ecological understanding, which can be no other than our best justified scientific insights.

This may seem a complicated task, but it functions much like fostering the health of a person's own body, which cannot be discriminatory with respect to the organs that constitute it, because a body needs all its organs to be healthy. This issue is of vital importance and requires careful meta-ethical argumentation (i.e., what is a good ethical system?), as it goes against much practical ethics and much economic practice, which tend to favor the most powerful or strongest at the detriment of the common good of all constituents. The resulting malpractice has lead to the dire predicament our whole Earth including humanity is in presently. We have to get serious about our Earth system being one highly interconnected organism [10]. This is a matter of proper understanding of what *ecology* or inter-dependency means, and the *integrative thinking* provided by humanism-cum-ecology is the way. It is the *Way of Life* [2].

I cannot give further argumentation in this paper on the issue of why an ethics based on supremacy[15] (personal or racial) is badly misguided, as this is a different topic, see, e.g., the book [5] for this, but here are a few further observations on the necessity of properly understood integrative humanism:

- Each human has a unique contribution to make and each human is subject to the same (life and death) predicament. One cannot separate life into "productive" and "unproductive" phases, or people into "valuable" and "not valuable" without destroying the basis of life itself with its intricate dependencies between all participants (see in this respect the view of modern genetics as described by Siddharta Mukherjee in [12]).
- All ecologically meaningful ethics has to be based on respectful sensitivity for the *whole world* we live in and *all* other humans. Caring selectively is not an option. Due to intrinsic limitations of human knowledge, selective care always degenerates into social irresponsibility, often even into downright crime, as was the case with Nazism, Stalinism, Mao-ism, Racism, and many other forms of discrimination. Respect for all living beings, their ecological role and their respective sensitivity is a reciprocal property[16] and therefore uniquely capable of achieving global health.
- The higher layers in the intelligent control hierarchy (societal control layers) are dependent on and need the input of individual humans: "higher" authorities, like governments or corporations, may try to control their underlings and the environment but are de facto primarily controlled by and serve the interests of selected people. These higher authorities may have a lot of power, but that power has often proven to be destructive toward the common environment.

[15] Sometimes erroneously called "social Darwinism," but there are many other varieties that posit the right of the strongest, in theory if not in actually practice.

[16] People will care for you if you care for them.

- Empathy and cooperation are the only methods for societal progress that respect the Earth's ecology.[17] Competition and respect have to go hand in hand, otherwise competition gets destructive due to its uni-directionality and hence becomes violent. Competition is necessary as an inducement to action and a guarantee for quality, but it has to be mitigated by commonly shared integrative goals.
- An essential but often overlooked argument for integrative humanism is skepticism about the comprehensiveness of any worldview the human mind may harbor, even using the best of science available. Any "fundamental" theory or vision our minds and science are capable of constructing necessarily results in a limited view (a model) rather than an exact rendition of "reality," due to the intrinsic limitations of our brain and our thinking processes. Nature and "reality" (that is, how nature presents itself to our experience) appear to be much more diverse and more complex than our laws and thinking are able to conceive and our models for reality are able to construct. The same can be said about personal or societal views on people and their behavior. This necessary skepticism is in stark contrast to the overly optimistic view of science propagated by modernist philosophy in the eighteenth century, but it is consistent with our present view on system dynamics, as described in a previous section of this paper.[18]

Well-understood humanism[19] is much more than an ideology, it is an attitude necessary to achieve global through personal health, whereby the well-being of humans in their environment is chosen as the primary goal of personal and societal ethics. Human health *needs* and at the same token *procures* societies' health, but can only be achieved through full ecological health of the Earth.

Nonetheless, all ethics must develop adequate controls to achieve its aims, and all control has to use some kind power. As we discussed in the section on system

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[17] Predators have a precarious existence. The cooperative mode is the mainstream method of survival of many species, even when unwittingly. For example, the symbiosis of plants and insects, or plants and mammals, not to talk of the symbiosis of mammals and bacteria, or plants and fungi, etc. Humans cooperate much more than they compete, if one considers all the cooperative effort that goes into education, household activities, care, culture, science, medicine, even in politics and business. We mainly compete to cooperate, but we also cooperate to compete although competition is mostly not the end goal, as it is in the Olympic Games—although even in that case one can argue that the end goal is the profit made by advertising agencies. Predation is not necessarily ecologically harmful, it is an element in keeping the ecological balance. It gets harmful when unchecked, and is then in danger of not only destroying the victims but the predators as well.

[18] It should be mentioned that the skeptical viewpoint is as old as philosophy, and perhaps its most essential ingredient, cf. Socrates' view on the deficiencies of language and Lao Tzu's warning on humans being "sorcerer's apprentices" as related to the accomplishments of nature.

[19] As conceived by its originators like Erasmus and Thomas More.

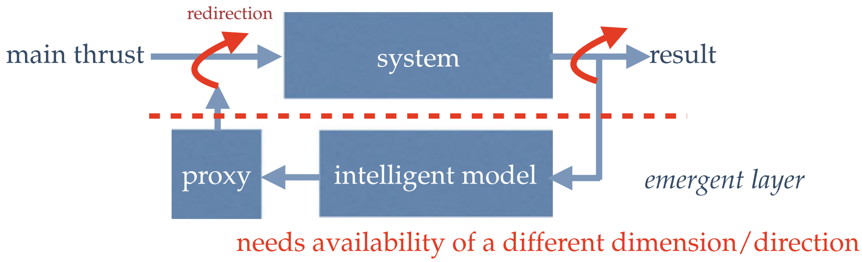

Fig. 4 Intelligence as an emergent layer using a proxy to control a process by deviating a main stream of power for its own benefit

dynamics, each level of control has structural and semantic relationships (it interprets and controls accordingly). It is dependent on its connections to "higher" and "lower" levels of emergence and on potential modes of interaction with those (e.g., via hierarchy, contracts, shared intelligence, semantic alignment) and on its own structural capabilities (sensing, interpretation, actuation). Control happens mostly through proxies, necessitating a different generic model than the traditional direct feedback control model, namely, a model that includes the contribution of intelligence, see Fig. 4 for a schematic. In this short paper, we cannot discuss most levels of intelligent control active in the Earth's ecology further. I have singled out the most important one for further discussion: economics.

4 Economics and Hard Measures for Sustainability

Economics provides the levers for the detailed management of our ethical future: there is no other sufficiently comprehensive control method available to humanity. As we know, economics is largely "ethically neutral" (although not everybody might agree), but it can be steered in many directions and by various mechanisms—a complex topic in need of intense exploration. If our ethical goal is to achieve sustainability, we need economics to achieve it. As we have experienced in the last three centuries, economics can easily produce tipping points and running away developments. Control on run-away economic effects requires countermeasures that not only aim at realizing sustainability (health) goals, but also mesh with the specific dynamics of the economic system to be effective. An economy has to be organized so that it is able to control itself.

Although the establishment of a sustainable economic system needs an outside authority to enforce the economic rules of the game, the economic system should largely run in an autonomous and distributed fashion, since that is its great strength. A "good" economic system is capable of embodying its own regulatory power, once well defined and implemented. Although authority is needed to establish rules of conduct, no dictator is needed to authorize operations, quite on the contrary: only general acceptance and automatic enforcement of the rules, with potential recourse to arbitration or judiciary in case of abuse or conflicts.[20]

This being accepted, economics provides for a long list of further potential choices, i.e., choices we make collectively at the various levels of societal activities and stratification ranging from the local private to worldwide global. These choices condition or even determine how we can realize our ethical goals. Let me mention a few (to properly detail them all, a much more elaborate treatment is needed, see, e.g., [14]):

- how to deal with "property," entailing rights to be claimed and responsibilities to be fulfilled?
- what are the rewards for labor and effort versus the provision of capital?
- how free are capital owners on the use and purpose of their financial potential?
- which economic activities are harmful and how should they be curtailed?
- how do public authorities participate in the economy versus private initiative?
- what is being taxed by public authorities and how?
- what proportion of public outlay should go to education, health care, commons, civil protection, defense? how does economics deal with social security, pensions, human rights (what are they?), the rights of future generations?, etc.

How all these choices are made is of course a highly political affair, involving large numbers of people messily organized in a great variety of constituencies and roles: a perfect breeding ground for chaos and emergence, where control is grasped by various agents and in various directions through tipping points that re-orient the focus of attention and determine the course of events competitively. This process is already highly "ethical" in that the participants try to establish what the course of events should be in their view. Ecological ethics has no other choice than to try to grab the attention of the human community with all its diverse constituencies to its concern for the well-being of the Earth, and strive at establishing proxies at the various available levels of potential control, from the local private environment all the way up to the whole world community.

Short of a utopian worldview, society needs means and power to achieve its ethics, whatever it is. What is called a "capitalistic economy" allows economic agents (persons, companies, authorities) to act independently, while providing the possibility of control through exchange of capital (costs, rewards)—we know of no other effective method to achieve such distributivity and versatility on a large scale. However, many of the economic means available in an open capitalistic system can become goals in themselves and violently subvert the process. Becoming "good" economists in the global ecological meaning of "good" has to be a necessary societal priority [14]. Without a clear definition of ethical goals and their translation in concrete economic action there shall be no viable sustainable ecology. Ecological ethics as a design

[20] This is in stark contrast to a system where every action or transaction must be authorized by a central authority.

strategy for the Earth's well-being has to go hand in hand with adequate (and even optimized) economic practice.

Similar to health and ethics, economics shows characteristic diseases. Here is a shortlist of what I see as some of the most important ones in present-day economics:

- large masses of ineffective capital (a huge proportion of moving capital is speculative) [sickness of means],
- accumulation of capital by economically ill-directed actors[21] [sickness of goals],
- "supply-side economics" instead of "demand driven" [structural incompatibility],
- ill-directed demand [semantic incompatibility],
- the whole list of ethical diseases we discussed before. The classification shows clearly in which directions solutions have to be searched: preventing disease *and* producing new healthy perspectives.

The effectiveness of economics is due to a good collection of potential controlling proxies available to economically active agents. To mention:

- rewards, subsidies, taxes, fines;
- availability of capital;
- the stock market;
- international associations and meetings;
- entrepreneurship;
- political activism;
- dedicated research;
- public opinion, social media;
- individual actions, customer's behavior.

All these proxies (and more) can be used for ecological profit. Here are some examples:
– the emission of CO_2 certificates has created a valuable economic proxy for the interests of the atmosphere. Admittedly, it is a beginning, but its value is undeniable, although it shows undesirable side effects that may worsen instead of improving the situation;
– guarantees of sustainability in the exploitation and marketing of natural resources such as wood and fish have influenced customer behavior, but, again admittedly, much more has to be done;
– the successes of bio-agriculture and bio-induced diversification have produced both a new attitude towards biologically sound production and consumer demand for it,

[21] Are we returning to a kind of *Ancien Régime*, whereby 2% of the population owns 98% of the wealth, while supply-side economists tell us irresponsibly that the remaining 98% of the population will profit from such a concentration because of a "trickle down" effect, the Earth's resources are being squandered for profit of the few, and a large proportion of the population struggles to come by? We know from history to which kind of disasters this leads.

creating a new type of diversified agricultural economy with its markets and profits;
– investments in both scientific and industrial research in alternative methods to harvest and store solar energy have dramatically changed the energy economy, in ways that were unthinkable only 15 years ago, clearly demonstrating the power of technology when well addressed and supported by industrial momentum;
and there are many more examples of successful development of economic proxies acting in name of the interests of the Earth, but much stronger action is urgently needed.

Which proxies and how to steer them in the right direction will be the core of the full throttle ecological ethics we need to develop. In particular, economic growth (necessary for economic health: economic growth should be seen as a *measure of effort* rather than a *measure of profiteering from nature*[22])—can be achieved by a strong emphasis on ecologically sound innovation, redirection of production methods, and the development of sustainable new products and services. Growth should not to be understood as "more goods and more commodities," but as intensified efforts to create "higher quality of life in a healthier environment" (such an increased level of activity translates in growth when measured financially).

The sky is the limit here: we can always aim at a higher quality of life, sustainable production and agriculture, better health services, ecologically sound mobility, a more attractive human environment, improved development of arts and culture, not to talk about enhancing our natural green environment with respect for the manifold of species that surround us, etc. There is no end in sight how we can obtain economic growth when we apply our economic and technical potential in the right direction. The key is *to generate tipping points in ecologically attractive directions*: our human intelligence should be able to create those (as it succeeded in creating the agricultural, industrial, and digital revolutions. Our next challenge is the ecological revolution).

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[22] Economic growth is strictly speaking not a systemic necessity, but we all know what a recession means in terms of societal disruption. Economic bubbles are caused by a chaotic run away of ill-advised actions, and, from an environmental point of view, investments in unsustainable depletion of nature or causing run-away pollution. Such investments are obnoxious and should be prevented by law. On the other hand, humanity has to put substantial effort in ecologically useful activities, hence creating economic growth in a desirable direction, which proves even more economically rewarding, since it involves a lot of people in meaningful activities, e.g., measured by the reward for their contributions. Nature does not get properly rewarded for its contributions, but people who exploit nature do, and this must change. But, similarly, people who contribute to nature's and people's well-being should get rewarded, which with nature profiting from it—*that* has to be the basis of economic growth.

How can such desirable sustainability be achieved? Inspired by the ideas of Amar Bidhé [1], Kate Raworth o.c., Michael von Hauff [17], Martin Grambow [7], Peter A. Wilderer [20], authors in this volume, and many others, here are some ideas on how the use of proxies applies to sustainability. One may distinguish hard measures to achieve sustainability and soft measures (not to be confused with "hard and weak sustainability" as described by Solow and Hartwick in the 1970s[23]). Hard measures consist of the whole gamut of governmental (and sometimes private) actions aiming at guaranteeing ecologically sound production and consumption, enhancing the economic position through public investments in sustainable infrastructure via public works and public services, preservation of natural heritage (forests, species, water supplies, research), development of the "commons" (all the public areas), tax breaks and subsidies for ecologically meaningful activities, and many more. All these involve judicious use of public money (tax payers' money!), but one should not forget that somebody's cost is somebody else's profit. Money is cost/reward neutral: it does not disappear, it just changes hands. The whole economico-political game is about achieving the right balance, and, of course, keeping the books in the black and achieving sustainability at the same token. All this cannot be done without a massive redirection of economic activity, and will require great economic expertise and political acumen to realize, but it is the way to go.

It is not the place here to make an inventory of economic measures that can be taken to steer our economic policies into an ecologically sound direction. Quite a few economists have produced recipes for this, let me just mention Raworth again, but also Piketty [13] and Stiglitz [9], and many others in their tracks.[24] Let me suffice with making arguments on the economic value of an ethical approach in which quality control is given priority, as exemplified by some selected cases. One only has to look carefully at what happened with modern industrial production, in particular, in the manufacturing industry. Competition on quality has become global, meaning that only the very best products make it on the market. Inferior quality is easily pushed out of the market by a qualitatively better product. Just think of the massive increase in quality of computers, mobile phones, cars, televisions, not to speak about a variety of services like banking services and transportation. Increase in quality has tremendous economic value, and companies like *Apple* or *Samsung* have built their market position on the quality they offer, squeezing out lesser players or players who did not succeed in catching up with the quality race. The issue we face with Earth ecology is not the economic value of "quality," it is *what is considered "quality" by the market and the human community*. *We badly need a quantum change in ecological quality awareness throughout our global human society, from personal habits to companies and governments*.

There is an intrinsic, functional component in the quality of a product, but also, and very importantly but often neglected or ignored altogether, an external one, namely, the impact a product has on the environment. Many modern products may be very good technically, but poisonous or toxic when considering the ecological footprint

[23] I am grateful to Michael von Hauff for pointing this out to me.

[24] Even Adam Smith stated that capital should not be hoarded, but invested in productive activities.

they leave behind. Similar to how the use of mercury or lead has been found to be highly poisonous and unhealthy, we are now realizing how poisonous the use of plastic packaging is, the burning of fossil fuel, the mining and use of various toxic minerals, agriculture based on monocultures, etc. It is eminently clear that we all must extend the scope of our concern for health to our whole environment, if only to keep ourselves healthy. This means that the ecological impact must come to the foreground in almost any economic activity: we must require a *cradle to cradle* sustainability of the products we buy or the services we get, i.e., sustainability throughout the whole lifetime of a product or process [11].

Let me mention a non-exhaustive set of measures that help to achieve this transformation:

– strict regulations on acceptable materials, their mining, usage and disposals, as well as strict standards on production processes, requiring industry to use sustainable materials and production methods throughout. Products may temporarily become more expensive because of this, due to necessary research and development, but typically end up being both ecologically sound *and* cheaper;

– the mining industry needs strict regulation so as to create a level playing field for non-destructive competition in this ecologically highly sensitive area. Ecologically dubious materials (like Cobalt or Uranium) have to be replaced with sound alternatives (e.g., Cobalt is gradually being replaced by less harmful materials in Lithium-ion batteries, and better alternatives are actively being researched). Finding adequate low cost and sustainable replacements (like functional organic material) may be costly initially, but the rewards are great in the longer term. A tipping point effect may be produced here when the potential future rewards of alternative investments are understood and communicated;

– the nefarious effects of various types of ubiquitous pollution (gasses in the atmosphere, plastics in the oceans, water pollution on land, increasing warming) are forming a major threat to the health of individual people and the ecological health of the planet. Producers and distributors (the packaging industry, supermarkets, transportation systems) must change the ways in which they are offering their goods and services so that they do not produce wastes that end up to be unredeemable toxic. Such practices must be forbidden categorically;

– a similar argument has to be made concerning large parts of agricultural practice: mono-cultures (be it of crops or animals) on a massive scale must be systematically discontinued. Technology may bring at least a partial solution. The development of large mono-cultural areas is motivated by economic arguments, in particular efficiency of production and low cost. But the resulting products are qualitatively inferior (often having low or dubious nutritional value), the massive use of industrial fertilizers is poisoning aquifers and rivers, and the mono-cultural mass production generates all sorts of nasty ecological side-effects like the need for poisonous chemical "pest" control on a large scale, not to talk about the loss of a lot of bio-diversity, with, again, nefarious additional side effects. Massive use of chemicals threaten the general health of the population as well. The industrial production of meat, fish or eggs results in hugely inferior quality of life of the concerned animals themselves and dubious quality of the products. This whole sector is not only a disgrace to humanity, but also a threat to it. Strong regulation of agricultural practice systematically preventing unhealthy practices is evidently needed, whereby the notion of "unhealthy" has to be expanded to "ecologically harmful". Hence, not only the use of noxious chemicals or the production of unsustainable wastes is unhealthy and has to be unequivocally forbidden, but also massive incarceration of animals, large monocultures etc.

– a related problem is the economic tendency of "running to the bottom", which has to be prevented when it is threatening ecological health. For example, due to the remarkable upcoming of sustainable energy production (thanks to the upcoming of photo voltaics (PV) and wind energy) an unhealthy competition has arisen between sustainable energy production and the oil-mining industry, resulting in slowing down the swift deployment of sustainable energy. The consumer may get cheaper energy this way, but at the cost of poisoning the earth's atmosphere much longer than needed. There should be no competition that pits healthy solutions against unhealthy ones, and the use of fossil fuel in an unsustainable way should be strictly prohibited by law. It has been an incredible luck that sustainable energy production has become so lucrative so quickly (who would have thought of it fifteen years ago?), but that has also an undesirable cost, namely that only massive production of generators (PV cells or wind mills) with perhaps dubious means achieves the low cost aim. Similar "running to the bottom" pits sustainable agriculture against monocultures. The solution is only possible via "hard measures for sustainability", namely the enforcement by law of ecologically acceptable production standards for all sectors of industry. It is not unusual to force industry to adopt standards, e.g., safety standards. Sustainability standards deserve the same status. The advantage of enforced standards is that they create a "level playing field" for all participants.

– capital, which is presently phantom-ing around the world purely speculatively, should instead be channeled into ecologically sound and productive activities. Economists have an essential contribution to make here. Our financial system has to be reformed so that investments in ecologically sound infrastructure is rewarded (energy distribution, mobility, public and green spaces, community services, education, research) on the one hand, and speculation discouraged on the other. (An idea is to use alternative payment systems, different kinds of currency like vouchers to achieve specific ecological effects. Another is to systematically reward ecologically useful contributions by the public at large, thereby offsetting eventual costs of ecologically better products—but I have to leave this area of thinking to economists.). There is also a role here for public authorities to devise schemas that make investments in ecologically sound technology less risky. To achieve such endeavors, we need, according to D. Holemans, a new social contract, let us call it a "socio-ecological contract" and start working at it [8].

It should be clear that economics for an ecologically healthy world requires strong public regulations. Some people see this as "preventing freedom" both for entrepreneurs and consumers. It is a foolish idea that economy can flourish without strong regulations, just like it would be a foolish idea to assume that you can have good mobility by car without well-organized roads and traffic rules, or global capitalism without protection of capital and property. No freedom without discipline!

Our Earth baths in solar energy. The supply is inexhaustible, and we have all the technical know-how to harvest it directly, without recourse to harmful secondary processes, like fuel burning or nuclear energy. *Ecologically sound energy production should not be a problem at all for our technologically savvy humanity!* We are also creating other, sometimes extremely dangerous, shortages of resources, and we have a number of incredibly valuable gifts of nature that we are squandering without consideration as well. We have, for example,

- a great variety of fellow species that make up our ecosystem. We badly need their contributions and should keep our overall environment attractive for them as well;
- pristine sources of water, air, and other essential materials that we should use in a considerate manner by recycling them properly after use, to perpetuate their value for the future;
- natural resources such as oceans, forests, great varieties of plants, glaciers, rivers, skies, all of which must be kept in sustainable balance with each other and are threatened by our inconsiderate activities;
- the gift of intelligence, of culture and of ethics, which allows us to be conscious of the value of our Earth, and which pushes us to take the right actions to make our planet healthy, sustainable, resilient, and therefore beautiful again.

In theory, the ecological problem of the Anthropocene is not impossible to solve. It is a question of societal engagement, courage, and entrepreneurship. Some adequate measures are under way (as already mentioned), but what is being done is largely insufficient, and, moreover, it is being countered by ill-advised and even criminal actions by all sorts of sick side interests that use similar control mechanisms as those at our disposal, like a cancer attacking a healthy body. Economy is not there to prevent healthy developments, but, on the contrary, to facilitate them.

5 Soft Measures for Sustainability

All the hard economic measures to achieve sustainability will, in the final analysis, be critically dependent on what are necessarily soft measures. These are measures that aim at a global *cognitive change* concerning humanity's perception of the state of our Earth and the necessity of adequate ethics as a new layer of quality control on humanity's behavior. This is a fertile area for *tipping points* as was so beautifully illustrated by the single high school girl Greta Thunberg on *Skolstrejk för Klimatet* causing a worldwide revolution, much like a butterfly "causing" a tornado (think about chaos and emergence!).

Political and economic measures only go so far as public awareness of the main issues and acceptance of the consequences go. To achieve any kind of effective behavior, large *semantic alignment* between all constituents of society (or, equivalently, mutual understanding) is needed, based on a shared perception of truth, open communication channels, education, and cultural sharing, all to be carefully fostered using human intelligence, respect, and technical know-how—see Fig. 5.

Hard measures for sustainability are also hard to take, because they are experienced as coercive and often disturb the existing order, even when that order is demonstrably harmful. People do not like to change, neither their ideas nor their habits, especially when they are perceived as beneficial to themselves. People might even go to war to preserve their privileges. It is a sad corollary of humanity's recent history that the systematic destruction of nature (including many lives of inhabitants) in what is called "developing countries" has been the instrument of economic prosperity of "first world countries." Financial interests have been for a long time the prime and foremost object of public protection, no matter what the cost to nature

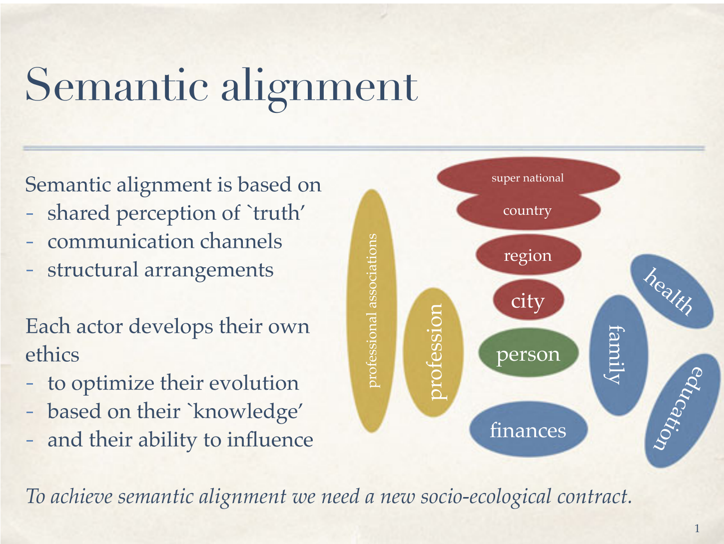

Fig. 5 Semantic alignment across many actors and many modes per actor

and humans was. We now understand that this is a fundamental if not foolish error, because nature's health (including human health) is a much more basic necessity. Nature's health is too precious and should not be made subservient to the quest for opportunities, gain, and profit, but this is an insight that is not yet largely shared by the powers in place, even nowadays after so much evidence of a run-away ecological health crisis.

Semantic alignment is a necessary condition for a successful transition to a sustainable Earth. As indicated in the previous section, more is needed, in particular hard measures, but without semantic alignment, many necessary measures and efforts will find insufficient support, and the end result will be nature running out of control, at least as a benign habitat for humanity (as already mentioned, nature has its own ways to deal with human insufficiencies, the recent pandemic being one "good" example.).

In the section on system dynamics, we saw the role semantics, as giving meaning to observations, plays in system control. Intelligence controls an underlying system by accurate sensing and careful evaluation of the consequences of its control actions, which often happen through proxies. Intelligence hence plays a central role as an emerging controlling layer (there are, of course, other controlling agents, often even outside our perception or knowledge, but intelligence is the one we are endowed with). Correctness and trustworthiness of evaluations and resulting actions by humanity as intelligent agents influencing Earth's ecology become a paramount necessity and criterium of quality.

"Semantic alignment" is no easy matter, but it is essential. There is a large number of human-related agents active in the ecological field (in alphabetical order): civil servants, companies, consumers, designers, employees, engineers, executives, entrepreneurs, farmers, governments, investors, lawyers, ministeries, parents, politicians, scientists, teachers, tribunals, workers, etc., all engaged in some form of "model-based control," all entertaining their own "models" and their own "control proxies." No doubt a very complex and chaotic environment in need of, or subjected to emergent processes, which attempt to align both their models and their proxies.

A couple of examples may illustrate some of the mechanisms:

– a prime example is the sustainable generation of electrical energy. We may perhaps be confident that a tipping point has been reached, and that most energy production in the future will be sustainable, using the immense influx of solar energy as a source (through photovoltaics, wind energy, biomass conversion, or other sustainable ways). How has this, 15 years ago almost unconceivable, been playing out? Actually through an unholy combination of technological know-how, large-scale production and low-price economics that precipitate the transition. Yes, pure scientific and business intelligence have contributed, but what has caused the tipping is clearly effective industrial policy and consumer behavior conditioned by run down pricing. Intelligence has played an important role in creating favorable conditions (like much better solar cells, or enticing subsidies), but originally unforeseen other factors like low prices, the result of massive Chinese investments, have clinched the tipping. Even so, the tergiversations around the CO_2 tax show how important semantic alignment is (the present equivocation is to the detriment both of the economy and the ecology!). The ways of intelligence are often devious.

– Another, not yet realized but very important example, is the need for a tipping point toward sustainable agriculture and fisheries. Monocultures and large meat production facilities (I do not want to call them "farms," they are factories with production lines, where the robots have been replaced by animals) using incarcerated animals have to be stopped unequivocally, yet many new ones are being build presently, purely for economic reasons, namely, economy of scale and consumer demand for cheap meat (not withstanding the low quality). To get out of this bind, the consuming public has to start understanding: that it contributes to these evil and even criminal practices by its behavior as consumers; that, on the contrary, sustainable, distributed, bio-diverse, and animal friendly agriculture has to be promoted and developed; that politics has to create the conditions necessary for this to happen; that agricultural technology has to be developed that makes the turnover economically attractive, etc. The conjunction of all these efforts is "semantic alignment," where all parties involved develop a multi-faceted but coherent evaluation of the situation (the model building) and start agreeing on the ways to deal with it (the proxies). A big task for our collective intelligence!

Semantic alignment is often the result of an emergence. An illustrative case is provided by *Facebook*. Originally, the picture'world created by *Facebook* seemed innocuous enough, but it soon conquered the "real" world with its novel way of communication, thereby providing new ways for people to influence each other and settle opinions in their minds—it is a semantic alignment machine. One can now safely say that our youth is consulting *Facebook* and *Instagram* more than their school books, a library, *Wikipedia*, or even their teachers and parents. This is not necessarily bad, but the information chaos created by *Facebook* is in urgent need of further emergent control. Creation of new media is great, but each such creation needs novel control methods to avoid societal or ecological disintegration. We have indeed witnessed in recent times the successful misuse of social media for political purposes (think of conspiracy theories), thereby giving an impressive example of tipping points in public opinion (this is often referred to as the production of false *memes*, a fitting reference to the exponential propagation of genes in genetics [4], now *memes in "memetics"!*). This meme-reproducing ability shows both the dangers and the possibilities of our novel social media, and the challenge ecological ethics faces to anchor its vision. There is, in particular, an extreme need for education of the public at large and our young generation, in particular, since they must learn to distinguish between good and bad memes, accept what is valuable and reject what is not.

"Semantic alignment" in society should be based on the perception and propagation of "truth." Although people generally think that there is only one truth, a closer look shows that this is not the case. There are many shades of truth, because truth is not only dependent on *what* is being considered or observed, but also on *how* the consideration or observation is made and *how it is interpreted*. There is a fundamental human limitation in this process, which is closely related to the human capacity of knowing and understanding. This capacity is always limited, because it is necessarily based on a relatively small number of priors, and is moreover dependent on the scope and status of knowledge. Knowledge and experience (experience, science, technology) is largely shared between humans, but also this process is not univocal. Knowledge is never absolute. We are highly dependent on repositories of knowledge that we are able to share and, in the best cases, represent the actual status of understanding. The quality, correctness, and relevance of common knowledge remain a central issue, which we can also call the "ethics" of knowledge, namely, how "good" is what we believe to be true? As argued before, we generally accept scientific knowledge as trustworthy, with the qualification that its validity only reaches so far as covered by the precisely circumscribed experimental environment, i.e., an environment in which the validity of the set of prior assumptions and their scope of applicability holds. In the section on system dynamics, we saw that even in such rarified circumstances (e.g., like the particle accelerator at CERN in Geneva), chaos, and emergence reigns. That is the central status of the concept of "life" in biology even more. But... there is much more than scientific knowledge that has to be shared by the human community.

We lead our lives according to a number of assumptions, believes, and precepts that have an existence of their own (like memes), although there are means to assess their trustworthiness. What we call *wisdom* is of that nature, or, for that matter, ethics (in the Socratic sense). Also, what we consider valuable, what we find beautiful, how we approach other people, how we deal with our children, how we evaluate people's behavior, our attitude with respect to nature, what we consider important, etc. Necessarily, the whole realm of culture goes way beyond the strict assertion of verifiable truth of science, although it may be based partially on science, and should likely not contradict science and experiments, if it is to remain productive. Culture is an emergent layer with respect to science and other layers of knowledge and experience. Although every type of science has to adhere to strict procedural rules to be trustworthy, much of culture is based on imagination, exploration, and experimentation (creative thinking and feedback from other people and the community). Such an emergence is a characteristic of life!

These considerations put in context what semantic alignment actually means. Humanity cannot agree on a single set of truths: such a set just does not exist. Science is not univocal: every type of science is dependent on a set of priors, namely, the definition of its object matter and prior axioms or assumptions. Particle physics deals with elementary particles. Biology deals with live and how it progresses through procreation, etc. Every science is limited by the context of its subject matter and how that subject matter is best represented, *there is no universal science for nature with its permanently evolving and changing multilayered emergences*. Nonetheless, the scientific approach is to a large extent trustworthy, so long as its contentions respect their limited experimental context. Humanity has no other choice than to try to agree on a collective behavior that (1) respects the scientific knowledge for as far as applicable and (2) aims at overall well-being of organism Earth. Such a set of behavioral principles cannot be static, but will continuously be dependent on ever limited, adapting, and evolving scientific insights and cultural practice. This is what semantic alignment has to achieve: a dynamic cognitive coherence on the issues of global importance.

Semantic alignment has to happen across a great variety of human experiences and expertises, exemplified by the variability of human culture. There is a lot of work to be done in this respect, let me just mention some of the many issues:

- develop respect and understanding for humans across cultures and religions;
- understand the organic relationship between humans and nature;
- understand and respect nature's integrity;
- support the development of knowledge on ecology and sustainable technology;
- foster critical acceptance of scientific truth; and
- cooperate to prevent harmful actions.

Semantic alignment has to give shared meaning to all the notions mentioned (by "shared" is meant: a common context of understanding both on subject matter and resulting consequences). We cooperate effectively, not because we know everything, but because we know how to value and respect the knowledge of others, having learned to assess and integrate its trustworthiness.

In the case of ecological ethics, we dispose of a substantial body of scientific evidence on what is good behavior with respect to the Earth's ecology, i.e., good for the symbiosis of humans and the whole Earth's environment as an integrated organism. Although only few specialized people can understand the science behind global ecology, most people can understand the consequences of human actions, as carefully evaluated by science. It is then critically important that such "behavioral" information is communicated to and accepted by the human community at large. *Humanity as a whole has to become conscious of the need for global resilience and QoL-driven ecological ethics.* This means: semantic alignment across all the stratifications of human society, namely, countries, professions, political systems, religions, cultures, businesses, schools, ministries, etc., in the same way as most of us accept the necessity of freedom and safety. At the same token, we must dispense of false memes and foster convergence on what is truly important for our global future well-being.

6 Concluding Remarks

1. Ethics as "what makes a good life" is the definition of a quality design goal. In the case of "what makes a good Earth," ecological ethics aims at inducing all actors to strive at a healthy Earth, assess the ecological quality of their goals, and to act in sustainable ways.
2. Turning human, economic, and industrial activities into ecologically sound processes requires large investments, but can produce large profits and provide employment for a great number of people. Economy thrives on change. Economic growth should measure the level of productive and sustainable activity rather than the depletion of natural resources. A massive deployment of adequate technology is continuously needed to achieve the quality objectives of an ecologically sound industry (e.g., cradle-to-cradle sustainable products).
3. The capital needed to achieve the turn to ecologically sound production is often in the wrong hands. A central problem in modern economics is to turn speculative capital into (ecologically sound) productive capital. Adequate measures for this must be developed by economists, and implemented by legislators, banks, companies (driven by consumers), etc., leading to necessary *hard measures for sustainability* that reward healthy behavior and prevent ecological damage.
4. "Semantic alignment" or mutual understanding between the many players on the world scene is the key factor to achieve a consensus on the path to be followed to achieve sustainability and QoL. Semantic alignment requires *soft measures for sustainability*, i.e., conditioning measures in education, social media, politics, research, and development.
5. To focus its actions in the right direction, humanity needs to create "tipping points" that generate massive change in the public understanding of ecological necessity, following the example of Greta Thunberg and leading to a new world order (a new *social contract*) in which only ecologically sound activities are tolerated and QoL of the Earth's symbiosis is the prime focus.

7 Glossary

Agent	An independent entity capable of interpreting observations and influencing a system;
Chaos	Extreme sensitivity of the evolution of a system to variations in initial (or earlier) state conditions;
Cradle-to-cradle	In each and every stage of production, from origin to disposal;
Control	action by an agent on the dynamics of a system;
Dynamics	How data that characterize a system change with time;
Emergence	A novel order generated by a complex dynamic system, obeying new laws not covered by the basic laws, but observable by external agents;
Ethics	Behavioral goals and intentions (whether conscious or not); *ecological ethics*: the collective behavioral goals and intentions of humanity with respect to the Earth's ecology;
Measures	Institutionalized control; *hard measures:* enforced societal constraints; *soft measures:* measures that aim at shared cognition;
Resilience	Adaptivity of a system's structure and dynamics to external disturbances;
Semantics	The meaning of a phenomenon as interpreted by an emergent agent; *semantic alignment*: agreeing on meaning and significance;
State	Time-evolving data characterizing a dynamical system;
System	A set of entities that have constitutive structural relations; *dynamical system*: a system whose structural relationships evolve coherently in time; *distributed system*: a system consisting of many independent but interacting agents;
Tipping point	The start of a fast growing emergence.

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The Complexity Trap: Skepticism, Denialism and the Political Epistemology of Climate Science

Franz Mauelshagen and Walter Pfeiffer

Abstract The complexity trap snaps and gives rise to misconceptions and even denialism when scientists leave their narrow field of expertise and uncritically use their well-trained epistemological concepts in areas where they do not apply. This mechanism is rather universal and affects in similar ways non-climate scientists in their assessment of climate science results, specialists in a climate science subdiscipline in interdisciplinary controversies, and climate scientists participating in the complex socio-economic process of policymaking. Awareness of the complexity trap mechanism is the first step to avoid being caught in the trap.

Keywords Climate science · Global warming · Skepticism · Complex systems · Science–policy interaction

1 Introduction

Society's evolution in the last couple of centuries since the dawn of industrialization has largely been driven by scientific and technological advancement. Science and technology particularly enabled exponential growth of the global human population, historically unprecedented levels of energy consumption and per capita productivity. However, it was an unforeseen consequence that the industrial transition and the expansion of its fossil energy regime would reach a level of impact on the global ecosystem, even the entire Earth system, at which further growth endangers the future of our present civilization.

It becomes increasingly evident that only transformation toward a sustainable economy can secure high standards of living, which to this point, under circumstances created by the fossil energy regime of industrialism, has come at the cost of an increasing ecological footprint. Again, science is essential to provide society

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with guidance and orientation in the future transition. Today, climate science has achieved a leading role in steering our global society toward sustainability. In open, democratic societies, scientific knowledge and consensus must be communicated hoping to convince a large majority of people to support, or at least accept, measures toward sustainability and climate protection. Only then will effective policies be implemented. It is important to note that scientists, not only climate science experts, have a high responsibility in this communication process. Non-scientists expect that scientists, in general, will be able to expertly assess and communicate the findings of climate science. This expectation involves questions of reliability and public trust in scientific expertise. In the case of climate science, general trust in the scientific consensus on anthropogenic Climate Change, although well-established [1, 10, 48], has been under fire from lobbyists and "merchants of doubt". Contrarian scientists, conservative or right-wing think tanks and private corporations financially support pseudo-science and campaigns against climate science and scientists (for a list see the appendix to [21]).

A lot has been written about these campaigns and Climate Change denialism in general [21, 25, 44, 67]. Moreover, Naomi Oreskes and Eric Conway have published an account of the history of Climate Change denialism in the USA revealing who the merchants of doubts are and which private companies are supporting them [49]. The authors also showed convincingly that their strategies resemble the previous denial of the dangers of smoking. Like Oreskes's and Conway's, most studies on climate denialism focus on Anglo-American countries. This is also where Climate Change denialism is most common [4, 50]. It may not be fully explained by the success of "merchants of doubt" alone, there may be other reasons in the history of these countries as well [19: 138], about which we do not want to speculate here. In any case, there is evidence that scientists denying anthropogenic Climate Change were, in some cases, also paid by the fossil industry and other interest groups in Europe.[1]

From today's perspective, two decades of assertions by denialists that global warming is "a hoax" look like an early writing on the wall of the post-truth politics that has infected the American political system like a disease since the presidential elections of 2016. Unforeseeable in the 1980s and 1990s, the Republican Party has slipped deeply into the business of denying anthropogenic Climate Change following the millennium turn [9]. Recent statistics by the Yale Program on Climate Change Communication nevertheless suggests that denialists are losing ground,[2] despite a general declining trend in trusting scientific expertise [46]. Like in the USA under President Donald Trump, the rise of right-wing populism in Europe and Latin America might well lead to a new wave of denialist attacks on climate science [42]. It is a symptom of the current political atmosphere that fact-checking has become a

[1] Recently, allegations that this was the case with the chemist Frits Böttcher (1915–2008), a former Club of Rome member, were published by investigative journalists working for the Dutch *Platform Authentieke Journalistiek* under the headline "Shell Papers", as was widely reported in international media in February 2020. See https://authentiekejournalistiek.org/portfolio-item/shell-papers-wob-naar-de-wob-want-overheid-zegt-nee/. Accessed 23 Feb 2020.

[2] See, in particular, the Climate Opinion Fact Sheets on https://climatecommunication.yale.edu/visualizations-data/factsheets/. Accessed 27 Feb 2020.

frequent occupation, if not an obsession, in the news media and beyond. A similar practice has long been established in the public debate on Climate Change. There are a number of webpages, some run by respected climate scientists, presenting climate science in accessible ways and refuting many of the standard arguments brought forward by climate denialists.[3] There are, on the other hand, various sources that promote these same arguments time and again, and there are scientists who support such efforts claiming they have the expertise and authority to challenge climate science.

In this chapter, we refrain, for the most part, from involving ourselves in controversies about truth and facts. Even where we touch such controversies, our guiding question is why (some) scientists have become collaborators in the denialist agenda, for example: by participating in conferences such as the "International Conference on Climate Change" organized by the Heartland Institute, one of the fossil industry-financed conservative think tanks mentioned above, between 2008 and 2015. Many of these scientists are claiming an expert position on Climate Change, while they have no proven record supporting that claim. Without doubt, one reason is that climate science today is rooted in Earth system science, which means that it combines physics, chemistry and biology. This makes climate science accessible and open to critical assessments from these traditionally separated spheres of knowledge. At the same time, this epistemic openness involves the danger of overconfidence and misjudgment on the part of outsiders resulting from a lack of familiarity with methodologies and common practices in climate science that these outsiders are either unaware of or ignore willingly. While it is true that climate science is an inter-discipline, it is a widespread misconception that scientists with an expertise in any of the contributing disciplines are a apriori qualified to talk climate science.

In order to show what may go wrong in such cases, we will delve deeper into the *epistemology* of climate expertise, which has been somewhat neglected in the debate. In other words, our reflections will be more about the *conditions of knowledge production in climate science*, not so much about specific knowledge or claims of scientific truth attached to it. The *character* of climate science—its interdisciplinarity, its complexity, its relevance for the future and its unique level of politicization—is more important for our argument than questions about facts and truth. This is not at all to dismiss such questions and theories of scientific truth as irrelevant. They are extremely important! It is merely that we seek to shed light on some of the dangers that scientific expertise is exposed to, because climate science is a highly complex system of scientific knowledge production with many disciplines involved and depending on high-level technological infrastructures. Hence, our question is not "Why to trust science?" [51], but why to *mistrust* non-expert scientists raising their voice authoritatively on issues of Climate Change. Matters are further complicated, because the consensus on Climate Change and its predominant anthropogenic character translates into demanding profound changes in economy and society to mitigate global warming. This defines the transformative character of climate science and adds

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[3] Best known is Stefan Rahmstorf's webpage *Realclimate*, http://www.realclimate.org Accessed 14 Feb 2020.

a political dimension to it, which is much more than a mere side-effect. No matter if considered desirable or not, it is, in fact, a cornerstone in the epistemology of climate science that cannot be ignored. The political dimension has posed enormous challenges to climate scientists, not least because it exposes them to a lot of criticism.

We will argue in the first part of this chapter that some scientists become Climate Change denialists, or at least openly oppose (some of) the findings of climate science, because they are falling into what we call the "complexity trap". This is partly due to diverging scientific cultures in dealing with uncertainties, which we will illustrate using the examples of high-resolution spectroscopy of simple systems and the investigations of complex chaotic systems. As we shall see, misconceived methodological approaches may distort the conception of scientific results for non-climate scientists, giving rise to over-skeptical or denialist positions. Another way of falling into the complexity trap, which we will discuss in the second part of this chapter, is by making sweeping generalizations about how the Earth system works. In the past, a lot of the denialist potential was generated from such generalizations based on specialized expertise in some climate-related field, for example: solar physics. While this type of argument has lost much of its power today, it survives from a period when climate science transformed into the kind of multidisciplinary field that it is today. Unsurprisingly, it is most often repeated by a group of elderly scientists who have failed to keep up with this process. Climate scientists are sometimes criticized as well, often by denialists, for their political efforts and direct collaboration with policymakers. In the final section, we address the political dimension, which adds another level of complexity compared with questions of scientific methodology and specialization that dominate the first two sections.

2 The Complexity Trap

Scientific expertise from outside climate science is one of the main sources of climate denialism. For the "merchants of doubt"—think tanks funded by companies for the purpose of discrediting climate science, political parties or representatives supporting denial etc.—scientists publicly expressing that they are skeptical about the consensus on anthropogenic Climate Change create references that lend authority to denialist policies. Of course, it is legitimate for scientists to publicly express their skepticism, and there is little doubt that this is honest in a lot of cases, or often was in the past. That said, it is just as legitimate to ask if non-expert scientists are indeed a reliable source? Are there, maybe, intrinsic mechanisms or possible pitfalls that might affect in particular scientists leading to failures in perceiving and communicating the results of climate science correctly? It might indeed be particularly tricky for non-expert scientists to correctly convey the results of climate science research. From the personal experience of one of the coauthors (Walter Pfeiffer), related problems are surprisingly common among physicists, that is: within a discipline that historically has acted as a blueprint for the scientific method itself [32]. One major pitfall is directly related to skepticism. The birth of modern science intimately relates to enlightenment traditions of skepticism. It is all about asking critical questions—any question that comes to mind, and if this does not receive a satisfying answer, a scientist might be inclined to dismiss a certain research area or at least to see it very critically. As we discuss in the following, this, in general, vital approach in science is prone to failure if misconceptions about an unfamiliar field of research come into play. Well-trained strategies or conventions might then be projected uncritically into that other field of research. We exemplify this possible failure for the case of physicists working in fundamental science and who are in their domestic field of research not dealing with complexity-related phenomena, such as criticality, self-organization or chaos. But note, this is only one possible example, similar mechanisms and pitfalls may well affect scientists from other disciplines as well.

Fundamental theories in natural science rely on simplicity (Ockham's razor). Accordingly, simple explanations are favored over more complex models or theoretical concepts. Nicolaus Copernicus's heliocentric model of the solar system was simpler, while it had no improved predictive power compared with the model of planetary motion in epicycles around the Earth. According to Ockham's razor, the simpler explanation wins. Later, the heliocentric model was rapidly improved and gained tremendous predictive power. In this respect, physics is a paradigm discipline where rather simple fundamental laws in mechanics, quantum mechanics, or special relativity have proved highly efficient and versatile to develop and control technologies that largely reshaped our society compared with its pre-industrialized state. So, it appears that the reductionism to simple fundamental concepts is highly successful.

Skepticism is one of the paths toward simplicity. By asking fundamentally "simple" questions, i.e., disregarding dogmas and conventions, natural sciences have reached their present, rather advanced status quo. People trained in these areas, in particular physicists, have learned from the beginning of their socialization in their discipline that asking simple critical questions, in other words: being skeptical, is vital, both for better understanding the basic concepts, and for advancing our scientific knowledge in general. In a scientist's domestic field of expertise, this skepticism is moderated by the scientific community as a community of established practices. We know whom to ask, which book or journal to read, or which alternative theoretical concepts to study in case we struggle to find answers to our "simple" questions. In rare but exciting cases, we experience that such a question then indeed leads to new scientific insight. More often, we realize that others had the same question before us, and it was answered a long time ago. It is exactly our ability to deal with these "simple" fundamental questions and answers that make us experts in a particular field.

Now, what happens when we leave the comfort zone of our domestic field of expertise and start applying our well-trained strategies of skepticism in a different, albeit somehow related field of research or disciplines? In this case, we lack familiarity with the different community and practices, and there is the danger that we might not even be aware of this. We would struggle to know which books or journals to read to get straight answers to simple questions. One rather safe solution would be to become an expert also in the new field. Realistically, achieving this goal is time-consuming, and, unless we spend a lot of time, we will reach it only on a rather superficial level. Without reflecting on these limitations, we might be tempted to insist on procedures that proved successful in our own field of expertise. As we discuss and exemplify in greater detail below, this is a risky approach and the resulting assessment might be based on unquestioned biases and premises. The misconceptions arising from this approach will likely harm our personal judgment. In the worst-case, sound skepticism turns into denialism. A third option, for those who have no time to become (part-time) experts or would like to spend their spare time differently, is to become aware of the underlying mechanisms that affect one's own judgments. This might help to be especially careful in the assessment of results from a different discipline. This chapter might help rising awareness for this third and maybe less time-consuming option.

Assessing uncertainties and communicating them to society is essential in climate science. If there are different strategies for dealing with uncertainties in different disciplines, this might be a case where non-expert scientists fail when they comment on climate science.

Dealing quantitatively with uncertainties is a key element of the scientific method. This should, however, not be understood in the sense that there is a universal way of doing so in all disciplines. In many cases where observations can be repeated, statistical uncertainties can be minimized. This can lead to truly surprising accuracies of scientific statements. The applied statistical method is based on the high-frequency approach [2], i.e., uncertainties are almost eliminated by massive averaging. Whereas this strategy is reliable and highly successful in the area of fundamental research and for developing technologies, it has severe shortcomings when the complexity of a research subject increases. Note, for example, that to the best of our knowledge, none of our present technologies relies on chaotic dynamics, i.e., one example for dynamical behavior of a complex system. Presently and maybe forever, there won't be complete theoretical models that fully capture the behavior of complex systems. Therefore, any scientific model of a complex phenomenon will have to deal with qualitatively different statistical and fundamental uncertainties. These go beyond uncertainties related for instance to the statistical interpretation of quantum mechanics that still allow a complete description of simple enough systems. In these cases, the theoretical predictions can be verified in experiments to ultimate precision and vice versa. For example, the spectroscopy of optical transitions in hydrogen atoms is today performed with relative uncertainties of about 10^{-12} and similarly, the theoretical description reaches the same accuracy [3]. Great care is taken to assess the statistical and systematic uncertainties of both experiment and theory. Consequently, any significant deviation immediately raises big concerns. For example, the recently encountered highly significant discrepancy in proton radius measurements [65] initiated, both an intense effort to better specify systematic experimental uncertainties and a reconsideration of the theoretical premises required for modeling the experimental results. Presently, the race is open, i.e., it might be that we are experiencing a significant glitch in the foundations of physics or maybe the systematic errors in the measurements are not yet well enough understood.

For complex systems such as a living organism or the global climate similarly rigorous testing of our model understanding is fundamentally impossible. Deterministic chaos might serve as an example. Deterministic chaos is defined by a rather striking behavior: however small the difference between two initial conditions is chosen the subsequent trajectories for both cases diverge exponentially, i.e., the difference between variables grows infinitely [56]. Note that this holds already for a classical system, i.e., intrinsic quantum mechanical uncertainties are not even playing a role here. In the case of deterministic chaos, predictions of the correct theoretical model and any observation deviate exponentially and it is actually a feature and not a shortcoming of the model. Not quite so obvious this holds also for complex systems that do not exhibit deterministic chaos. For a complex system singular deviating observations or partial discrepancies between model and observation cannot immediately falsify a given model for a complex system. However, for a non-expert, this is not always immediately evident. Being trained, for example, in fundamental physics relevant for high-resolution atomic spectroscopy possibly leaves one unaware of this limitation of the falsification strategy.

Note that there are numerous other pitfalls that follow the same mechanism besides the assessment of uncertainties. As another example, take oversimplification. If inadequate simple models from one discipline are applied for complex systems this leads to severe misconceptions. For example, applying a simple box model from combustion engineering [14] to the redistribution dynamics of the radiotracer ^{14}C introduced by nuclear weapons testing yields wrong carbon residence times, which can only be reliably identified in a more advanced model accounting for the complexity of the carbon cycle [33]. Hence, oversimplification here seemingly supports a denialist position. The lack of awareness about differences in other fields of research and its consequences form the *complexity trap*. This trap is not immediately obvious and seemingly many scientists working in fundamental or applied research are not aware of the associated pitfalls, in other words: they might get easily trapped. Why is that an issue?

In democratic societies, the opinion formation process in the present climate crisis is influenced, mediated and driven by different interest groups, with climate scientists, scientists from other research fields (in particular natural sciences), non-scientists and various other groups as relevant players. The non-expert scientists take an important and not always responsible role in the communication of climate research results to the general audience.[4] Non-scientists cannot easily differentiate between statements made by a climate scientist or a non-expert scientist, since the way how scientific knowledge is gathered and the inner workings of scientific communities are unfamiliar to them. Now, if a non-expert scientist makes skeptical remarks about some climate-related topic this is likely to be perceived by the non-experts as equally well-founded as a statement made by a climate science expert.

The complexity trap is most influential for non-expert scientists. Climate scientists have detailed knowledge of complex interdisciplinary climate research and

[4] Consider, for example, the impact of the 1973 Nobel Prize laureate in physics, Ian Giaever, https://en.wikipedia.org/wiki/Ivar_Giaever#cite_note-16 Accessed 27 Feb 2020.

established consensus among themselves about anthropogenic Climate Change and the most likely future climate developments. In contrast, non-expert scientists lack detailed insight but nevertheless perceive themselves as sufficiently well educated in the scientific method to assess and communicate the results of climate research. This potentially distorts the opinion formation in society and emphasizes unfounded controversies already settled among specialists. In this way, non-climate scientists can unintentionally become allies of denialist interest groups.

3 Sweeping Generalizations

Even experts from the disciplinary spectrum coming together in the interdisciplinary field of climate and Earth system science are exposed to the danger of falling into the complexity trap. This problem can be illustrated by denialist arguments that are based on sweeping generalizations founded on some deviating expert opinions related to climate science. For example, some scientists from the group of solar physicists have argued against anthropogenic Climate Change starting from the fact that solar radiation is the most important source of heat on the Earth's surface. However, this does not allow the conclusion that solar variability must be the dominant reason for Climate Change, as this simply ignores that there are multiple external and internal forcing factors driving the climate system. These forcing factors interact with each other and operate on a variety of timescales [20: 180]. Assessing the relationship between them requires Earth system modeling informed by historical data (reconstructions) on past climatic changes on various timescales.

Difficult and open to constant improvement as modeling efforts are, it is beyond rationality that some people doubt the validity of this approach and continue criticizing climate models for what they are by necessity—i.e., simplifications of an extremely complex system—, while, at the same time, holding on to monocausal theories of the solar type. The most obvious explanation for this stubbornness may be a lack of expertise in assessing alternative explanations or, in some cases, a narcissistic desire to place solar physics center stage no matter what. This may be human, but it is not very scientific. It looks even worse when the advocates of such theories ignore the data collected from satellite observations since 1978, which show a declining trend [18]. Denialist reports have frequently repeated false claims that solar activity dominates human influence from greenhouse gas emissions, founded on highly controversial statements that the global temperature record on the millennial timescale correlates with solar variability [27: 247]. The latter is a matter of some controversy between different studies (e.g. [55, 57]). However, even the boldest calculations of radiative forcing have failed to produce numbers anywhere near explaining global warming by means of solar physics. Logically, most solar physicists today define their role by improving solar modeling as an important part of climate models. But they do not doubt the dominance of anthropogenic forcing. Controversial questions are in other areas where scientific efforts are needed to improve modeling.

However, it is not in the interest of denialists or merchants of doubt to cooperate in such efforts.

Even for historical epochs of Climate Change, such as the so-called Medieval Warm Period and the Little Ice Age, the sun has lost its previously almost undisputed explanatory power. The role of solar minima like the Maunder Minimum (1645–1715) as dominant force during the Little Ice Age (c. 1300–1850) is no longer common sense as it used to be 30 or 40 years ago [40: 76–84]. The influence of increased volcanic activity, particularly in the last phase of the Little Ice Age [6], and internal forcing [66] have emerged in recent decades as parts of a more complex pattern of forcing factors, which is also applied to earlier historical periods of significant climate variability [8]. Moreover, recent millennial scale temperature reconstructions that include the southern hemisphere have found no evidence for global cold or warm epochs during the preindustrial Common Era. Global warming in the twentieth century was the warmest period for more than 98% of the globe, which makes it spatially as exceptional in the last 2,000 years as it is temporally, that is: with regard to the speed of warming [45].

Sweeping generalizations about the sun as the dominant natural force driving all climate variability are scientifically obsolete. Today, only very few scientists continue to collaborate in the denialist effort to obscure this fact. Yet, the solar myth is remarkably persistent in public discourse. This is probably best explained by the historical longevity of solar explanations for climatic variability in popular science—a tradition that apparently has survived in public memory. Perhaps in more than one way, this resembles the equally persistent belief in astrology and horoscopes in popular culture. Sunspots became subject to telescopic observation from 1610 onwards. Speculations about sunspots as indicators of solar variability started soon afterward, but it took some time before this relationship was confirmed by astronomy. Once it was, sunspots precipitated into popular culture and were frequently discussed in context with economic cycles (e.g. [30]) and other social and economic phenomena. It is the tradition of this kind of speculation and its popularization that defines the seductive potential of the "solar argument" and, therefore, suits denialist intentions particularly well. The psychology they can count on by playing down the unknown and, instead, reducing it to the supposedly well-known is a desire to ease our conscience and concerns about anthropogenic Climate Change.

A different version of a sweeping theory is that the Earth is too big to be harmed by any human action. The most general version of this theory about "nature" or the "Earth" has almost disappeared nowadays. But well into the 1980s, a number of scientists still underestimated the speed of anthropogenic Earth system change, despite a much longer history of early warnings against the obvious trends of industrial growth. There is a long tradition of such warnings starting from George Perkins Marsh's book *The Earth as Modified by Human Action* [37, 38]. Reports published in 1956 and 1990 provided surveys of human impacts on all parts of the Earth system [62, 63], decades before Paul Crutzen proposed to define a new geological epoch called the Anthropocene [11, 12]. Earth system science has substantiated the diagnosis behind this proposal that human activities have become the dominant force of Earth system change—not only of Climate Change but also biodiversity loss, ocean acidification, atmospheric aerosol loading, profound modifications of the phosphorus and nitrogen cycles, land-use change and stratospheric ozone depletion. Recent history itself is the power behind this shift. This is what the "Great Acceleration" graphs suggest, introduced by Earth scientist Will Steffen to describe exponential socio-economic growth after World War II and its impact on the Earth system [58, 59, 61]. More recently, the concept of planetary boundaries has been introduced, which is basically an attempt to measure the speed of change of critical Earth system indicators against the background ratio of change during the Holocene [52, 60]. This approach is open to further improvement. Collecting reliable information on all the critical indicators for the entire Holocene epoch remains one of the challenges. In any case, constant improvement in methodology and data collection is key to the advancement of science. In contrast to such efforts, sweeping generalizations look like bad excuses for protecting one's opinions rather than exposing them to be challenged by others.

Some arguments frequently repeated by denialists of anthropogenic Climate Change are variations on the theme of supposed human insignificance. For example, CO_2 is only a small proportion of the whole mix of atmospheric gases; that in Earth's history, CO_2 has always lagged behind rising temperatures rather than being the driving force [27] that the amount released from anthropogenic sources, mostly the burning of fossil fuels, is relatively small compared with the masses of CO_2 stored in soils, forests and oceans. These statements have been disproven in many ways. Most of them are mere *ad hominem* appeals with no scientific value, because the proportions chosen for comparison allow no conclusions whatsoever about the effectivity of CO_2 as a greenhouse gas. To put CO_2 concentrations into perspective, climate scientists prefer more meaningful comparisons, particularly those between industrial and pre-industrial concentrations of CO_2, which can be traced back hundreds of thousands of years based on the analysis of air bubbles in ice cores. Such comparisons show how far industrial concentrations have moved beyond natural variability over this entire period [29: 201]. However, in order to assess the contribution of industrial increase in atmospheric greenhouse gases to global warming, scientists calculate how greenhouse gas concentrations affect the radiative balance of the Earth (radiative forcing), which is the difference between incoming (insolation from the sun) and outgoing radiation. Radiative forcing and, more recently, effective radiative forcing, which includes temperature response, have become the gold standards in comparing different forcing factors. It is precisely such comparisons by which climate science came to conclude that anthropogenic greenhouse forcing has dominated natural forcing during the industrial era (since 1750), with a clear accelerating trend in the decades after 1970 [28: 649–740].

It is almost impossible to conceive that any serious scientist him- or herself believes typical denialist statements about CO_2 of the type we have quoted above. These arguments are obviously designed for making use of some kind of seeming plausibility for the purpose of seducing a non-scientific audience into believing that no harm will come from the unhampered release of greenhouse gases from all kinds of human activities. Just like in the case of the solar argument, expert as well as non-expert denialists can count psychologically on a collective desire to be relieved from concerns and responsibilities related to global warming. There is another psychological element that denialists can count on when making sweeping generalizations of the type we discussed in this section. Sweeping generalizations are always founded on simplifications that are scientifically unsound, because they reduce complexity in a way already falsified by science. In a scientific context, the burden of proof would clearly be on the part of denialists. But this burden may be turned against science in case denialists succeed in placing misleading conceptions in public discourse. In the public arena, the complexities of climate science pose the challenge to turn specialized knowledge into comprehensible concepts and arguments, which may easily work against science.

4 Transformative Science

Today, climate science has achieved a very high level of public visibility, which is predominantly a symptom of its level of politicization. It has become pretty common practice for climate scientists to translate scientific findings into calls for, and advice on, political action. Recommendations for policymakers have become a built-in element of press releases on scientific expert meetings or as part of scientific reports. These practices are by no means restricted to the IPCC framework. However, the level of science–policy cooperation on Climate Change is unique in the history of science. Today, as the Earth system interacts with the social system, the inter-discipline that is Earth system science also involves the social sciences and humanities. Since science-based calls for political action affect society, and action as well as non-action on Climate Change will affect the Earth system in one way or another, the whole system forms a complex network with multiple feedback mechanisms giving rise to nonlinear dynamics reaching from the local to the global scale. Dealing with this historically unprecedented level of complexity is clearly among the greatest challenges for society today.

Climate scientists are sometimes questioned for their proximity to politics, for making recommendations to policymakers, for predicting planetary disaster if anthropogenic Climate Change remains unchecked, and for arguing for major socio-economic transformations based on the urgent need for massive greenhouse gas emission reductions. Criticism has been voiced by sceptics and denialists to publicly discredit climate science. However, it would be too simple to identify this kind of criticism as merely denialist. The circle of critics includes scientists and researchers from various disciplines, politicians, journalists and other people, who are not necessarily doubting the findings of climate science and the predominant anthropogenic causes of Climate Change. Their criticism is rooted in (traditional) normative expectations of scientific neutrality and objectivity. From a political point of view, there are also concerns regarding the lack of democratic legitimation for political action based on the expertise of climate scientists. Political scientists have criticized top-down approaches in global climate governance for their supposedly "technocratic" attitudes [35, 36]. Climate science experts are also criticized for giving far-reaching political advice on socio-economic or technological change representing these as effective pathways to emission reductions without providing alternatives and without fully considering the cultural, social, political and economic complexities of transformative processes [26].

Diverse as this criticism is regarding its underlying motives and intentions, it is particularly interesting for us as it opens up a completely new perspective on the issue of complexity. To this point, we have discussed climate science in the context of an epistemic environment struggling, mostly for its disciplinary fragmentation, to deal with complexity. Hence the danger of some of the scientific criticism coming from other disciplines falling into what we have named the complexity trap. As we move forward to the implications of anthropogenic Climate Change for society, we reach a new level of complexity—the complexity of a transformative science. Transformative science more or less claims that there is a need for major socio-economic changes that should be politically implemented [54]. This is the case with climate science diagnosing that the cause of potentially dangerous Climate Change is anthropogenic.

The logical consequence of this diagnose is that, to conquer Climate Change, we need to control its anthropogenic causes, in other words: greenhouse gas emissions. This looks straightforward and simple enough. But it is not, as, both, scientists and politicians were to find out quickly following the foundation of the Intergovernmental Panel on Climate Change (IPCC) in 1988. The late 80s of the twentieth century produced an enormous level of optimism on solving all kinds of complex international issues dynamically, peacefully and efficiently, particularly when the Cold War ended rather suddenly and unexpectedly with the dissolution of the Eastern Bloc and the Soviet Union. This optimism also applied to environmental problem-solving. The Montreal Protocol to protect the stratospheric ozone layer, ratified in 1987, served as the model to international cooperation on controlling global warming. However, expectations that the international community of states would agree, in a binding treaty, to reduce greenhouse gas emissions just as easily as it agreed to phase out the production and consumption of ozone-depleting substances proved erroneous [34]. The difference is best explained by the universality of greenhouse gas emissions (in contrast with emissions effecting the ozone layer), meaning there is practically no human activity that does not produce them.

However, the world of greenhouse gas emissions is not flat. Industrial countries have developed high-emission economies based on the burning of fossil fuels. Therefore, this group of countries is historically most responsible for global warming, while developing countries have had lower emissions and less responsibility. This inequality in terms of causation adds socio-economic complexity to the scientific complexity of climate science and modeling; moreover, political complexity is added on top of this, as there are different states with different political regimes and emission profiles cooperating in a United Nations framework, which treats mitigation of Climate Change and adaption to it as one political issue among a mix of others such as development, trade, health etc. After all, solving the problem of anthropogenic Climate Change is not, what the United Nations (UN) were founded for in 1945. The declared ends of the UN were the maintenance of international peace and security, protection of human rights and socio-economic advancement.[5] Creating a United Nations framework for international cooperation on Climate Change resulted from an evolutionary process, which added the fields of developmental and environmental policies to the mix by connecting them with those ends. In other words, scientists and politicians argued that Climate Change (like other global environmental problems) poses threats to peace, international security, human rights and welfare.

The level of politicization of climate science today is, more than anything else, due to an institutional framework created by the IPCC and the United Nations Framework Convention on Climate Change (UNFCCC). The IPCC was founded in 1988, the UNFCCC ratified by 197 signatory states at the Rio Earth Summit in 1992. The latter has fulfilled the role of a United Nations Charter for climate protection. With it, regular conferences of the parties (COP) were established, which have kept climate negotiations going ever since and have guaranteed climate politics frequent public attention [13, 22]. This may be considered an upside for a field of research concerned with the future of the Earth and the existence of human life on its surface. However, the experience of three decades of constant public attention has also shown the downside of exposing science to unpredictable trends in political discourse and changes in the media landscape, for which scientists have no training to be prepared. “Merchants of doubt” and private media companies with a certain political agenda have frequently attempted to use this exposure as an opportunity to discredit climate science [49].

Looking back at the period of institutionalization and the bigger picture of world politics, it is easily discernible that international climate governance reached a new level of institutionalization precisely when the Cold War was about to come to an end. However, this should not blind us to the fact that this period was preceded by a state in the politicization of anthropogenic Climate Change very much influenced by the forces and interests of the Cold War superpowers. The Cold War with its characteristic competition between the USA and the Soviet Union is, in fact, key to the political epistemology of climate science, in particular its technological infrastructures and its political networks. This is crucial, because it explains why it was relatively easy for scientists to make their early warnings against anthropogenic Climate Change heard and bring this subject to high-level political attention.

One of the ways meteorology and climatology got involved in the Cold War is “weather warfare,” which uses atmospheric circulation and precipitation for military purposes. We know from a number of historical studies published in the last decade or two that both superpowers became interested in it even before the end of World War II [16, 17, 23: 165–188]. A wide range of weather modification technologies were patented, few were used. For example, the US military applied cloud seeding in Vietnam between 1967 and 1972 to enhance the monsoon season and provoke flooding [24: 218–225]. The New York Times reported about these secret operations on July 3, 1972, and afterward they became subject to Congressional hearings in 1974 [64]. The USSR used silver iodide seeding in April 1986, after the accident at the Chernobyl nuclear power plant, to make highly radioactive clouds rain over

[5] See the UN Charter as it was ratified in San Francisco 1945, https://treaties.un.org/doc/publication/ctc/uncharter.pdf (last accessed February 25, 2020).

Belarus before they would reach Moscow [7: 40–45]. In the Soviet case, these were the fruits of scientific efforts that had started in 1941 and precipitated in Stalin's plans for the transformation of nature [5, 47]. In the American case, ideas of weather and climate modification have an even longer tradition reaching as far back as the colonial period [15, 41, 53].

These examples and historical contexts must suffice here to illustrate some of the ambiguities surrounding the use of weather modification technology, be it for military purposes, or be it in the context of a state executing power over its own territory and people. Climate and Earth system scientists were involved in "cold war business" by the superpowers in many more ways than this. For example, atmospheric scientists and oceanographers did a lot of research on radioactive isotopes in nuclear testing areas and beyond. Geological knowledge informed the military sector in constructing missiles that would reach even distanced targets with enormous precision. Climate and Earth scientists learned how to use the extraterrestrial infrastructures provided by satellites for their purposes. In sum, following World War II climate science became a Cold War science. It is not at all surprising that this context guaranteed anthropogenic Climate Change a significant level of political attention. In the USA, it climbed the political ranks quickly once Charles Keeling's measurements, carried out at the Mauna Loa observatory since 1958, confirmed that CO_2 was indeed accumulating in the atmosphere. Warnings against the implications of these measurements entered the political sphere through the veins of the President's Science Advisory Committee (PSAC) in 1965, created in 1957 by President Dwight D. Eisenhower. This is how President Lyndon B. Johnson became the first Commander in Chief to mention Climate Change in a "Special Message to the Congress on Conservation and Restoration of Natural Beauty" [31, 39]. From then on, anthropogenic Climate Change became a frequent subject of scientific reports on behalf of the US federal administration and several of its institutions. Under the impression of the 1973 Oil Crisis, concerns about future energy supplies and the need to transform the energy system became the dominating framework for discussing Climate Change. Throughout the 1970s, and well into the 1980s, the energy question framed the early debate on anthropogenic Climate Change and helped increasing its political and socio-economic relevance [43]. The nuclear age continued to give political leverage to climate science, both, in the energy context and beyond, particularly through discussions of the threat of nuclear winter.

We stop our brief historical account here. For our purposes, it suffices to hint at the historical roots of the politicization of anthropogenic Climate Change, which we can trace back to the Cold War. There are many implications, which may follow from this; various conclusions are possible. While this largely depends on perspective, it would be too simplistic to consider climate science "contaminated" by the nuclear age and, therefore, discredited. Against the temptation of such moralistic simplifications, one could argue that the unprecedented dangers of the nuclear age required scientific reliability and increased the demand for (applied) scientific knowledge. The competition between the superpowers of the Cold War fostered technological innovation, which required high levels of control of complex and often dangerous technologies. This strengthened the ties between policymaking, the economy and science, which are essentially modern. In the nuclear era, it was logical for science to move beyond the framework of applied science and get involved in direct cooperation with policymakers.

It is in this context that we need to consider the evolution of science–policy cooperation on anthropogenic Climate Change as well as the meaning of high-level political Climate Change denialism. The withdrawal of the USA from the Paris Agreement based on publicly more-than-once declared denial of anthropogenic Climate Change by Donald Trump was a revocation of the standard, reached during the Cold War, that, for the welfare of all people, policymakers acknowledge scientific rationality. The significance of this rupture in modern history remains, even though President Biden has once again revoked his predecessor's decision.

5 Conclusions

There is a danger for highly specialized scientists to fall into what we have called the complexity trap—a mechanism rooted in the epistemology of complex systems which exposes scientific expertise to the danger of unnoticed lack of competence. In other words, (often) based on general attitudes such as skepticism, scientists tend to misconceive their competence in the unfamiliar environment of complexity science. The examples we gave in the first part of this paper were related to the disciplinary framework of physics; and we exemplified the complexity trap for experts and non-experts in climate science. However, it needs to be emphasized that similar mechanisms are relevant whenever interdisciplinary knowledge and discourse become relevant. Scientists are inclined to trust their disciplinary expertise, even in cases where their expertise is limited. To some extent, this is the historical heritage of long-lasting trends in scientific specialization. The effects, however, go beyond the realm of science and leave their traces in the wider public and political disputes about Climate Change.

Science–policy collaboration is a logical consequence of diagnosing that the global climate is warming due to anthropogenic emissions of greenhouse gases. Mitigating Climate Change requires global participation of all countries, particularly all major emitters of greenhouse gases. At some point in the process of diagnosing anthropogenic Climate Change, scientists have asked for political action, and politicians have then asked for scientific expertise to inform that action. As we have shown, science–policy cooperation on global warming emerged from the historical arena of the Cold War. In other words, the politicization of climate science is as much a *historical* fact as it is a logical consequence of the consensus that Climate Change is predominantly anthropogenic. Scientists both in- and outside the field of climate science need to recognize this fact and deal with it rather than complain about it or criticize climate scientists for a historical path taken by climate science, which is not a matter of choice and cannot be changed retrospectively. Radical "conclusions" from our awareness of this history, such as: that climate scientists should practice political abstinence, would not merely be unrealistic; they would be irresponsible.

That said, contributing in a responsible way to solving the problem of global warming is a permanent challenge to every scientist involved. The complexity of the problem, its economic, social and political dimensions, overwhelm the scientific expertise of any individual scientist involved. In a political environment, climate scientists themselves are in danger of underestimating this complexity, if only occasionally. Hence, Mike Hulme's warnings against the danger of "climate reductionism" might emerge from subordinating all governance issues to the priority of mitigating Climate Change [26]. Being a climate science expert does not necessarily qualify for assessing unforeseeable feedbacks on future developments of the socio-economic and political spheres. This is why the concerted expertise from multiple disciplines is required and needs to be integrated with a co-creative process that includes policymakers, stakeholders and other groups on all levels of governance. This is by no means a ready-made answer, but a current field for further explorations and experiences with newly designed political processes. Science–policy cooperation on anthropogenic Climate Change will continue to explore new pathways and participative processes to counter the dangers of reductionism. It is crucial for scientists participating in these processes to responsibly reflect their expertise and its limits.

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Biodesign: Design and Medicine—A Philosophical Challenge

Eckehard Binas

Man is the only creature who refuses to be what he is. The problem is to know whether this refusal can only lead to the destruction of himself and of others, whether all rebellion must end in the justification of universal murder, or whether, on the contrary, without laying claim to an innocence that is impossible, it can discover the principle of reasonable culpability.
—Albert Camus, The Rebel

Abstract With man being "the only creature who refuses to be what it is" (Camus), human culture is at times a dramatic image of enticing or revolting possibilities. The "conditio humana" thus cannot be understood without culture and this very excess of possibilities which culture creates at and in its borders by self-reflection. Design in the context of medicine means a demiurge in the substantial, an emissary for negotiations on the interdependencies of civilization and the conditio humana, and a functionary of success and beauty, monitoring a healthy or at least tolerable difference between reality and possibility. The design thus is applied cultural philosophy joining forces with plastic surgery and other, future disciplines of human remodeling.

Keywords Design · Medicine · Philosophy of culture · Conditio humana · Excess of possibilities

1 What Moves Us

When we speak of vulnerability and violation, and relate these terms to the Earth, to its external mantle (skin), to the conditions of its preservation and continuous renewal, we must acknowledge that we are talking about all or nothing. If humans were only able to think the big picture up until 150 years ago—as an idea, a construction, a model, found in a relationship between "this side" and "transcendence", today we humans have the power to take the big picture into our own hands. Here we

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have arrived at the epicenter of the realm of the "anthroposphere" challenge (the anthroposphere can also be understood as a complex system of energy, material and information flow), and that means at the point of the decisive influence of humankind on the entirety of living conditions on Earth. These affect not only humankind but also—quite obviously—everything, ultimately all life and its physical requirements. A whole generation ago, serious scientific studies such as those conducted at the Potsdam Institute for Climate Impact Research were already presenting authoritative mathematical models showing that the human is not only the most significant "driver" of Climate Change, but that we are looking at highly complex, multidimensional causalities of a global nature. When no rain falls in Brazil, when no Saharan sandstorm blows kernels of condensation to Europe, when the Labrador Current no longer drives the Gulf Stream.

This is an essential conceptual assumption, foundational for all the further thoughts and considerations here: geosphere and biosphere on the one hand and humankind on the other hand enter into (multi-)interdependent relationships. Today, this is happening to such an extent that historically speaking the humans' ability to adapt to their (self-)changed environmental conditions has been surpassed. Now, as the pendulum swings back, basically the adaptation of the environment to the human would be required. The question being posed and presented for discussion here, of optimizing the *"conditio humana"*, seems in this context to be a reaction of humankind to the environmental change which he/she has essentially brought about: What should and can humankind look like? Is he/she able to live in a devastated geosphere, continue to develop, and in the end also live a happy and meaningful life?

It is obvious that this adaptation does not happen like that, at least not in a way that can uphold a sustainable interdependence. Destruction is not adaptation! It is the human sawing through the branch he/she is sitting on. *Conditio humana* is not evolution at a standstill; the natural evolution has not swerved off onto a path of culture and closed down the natural path. In actuality, we have a correlation to look at, in which, more and more, there seems to be a one-sided determination, an irreversible intervention—even if "the Human" is (were) a cultural being able to learn and thereby influence his/her conditions in a concentrated, focused, interventionistic way (healing, conserving, revitalizing, etc.).

Taking this one step further, this concept of the mutual dependency of nature and *conditio humana*—which we must look at more closely later—applies not only to human's external nature but meanwhile also, and is just as essential a way to the human-ness itself, to internal nature. This is embedded in conditions of cultural development, which represent not only human's functional, form-created, experience-laden shell of physical things and determine how he/she acts and reflects from an institutional perspective but also for their part influence and change this nature more and more. This is the reason why it is futile in our context to replicate the standards of discussion utilized over the past 20 years: now, when considering the relationship between "bio" and "design", we are neither longer talking about aesthetic surgery nor about intervening in disturbed functions and processes within an organism, nor about corrections in the interpretation of "feeling good", satisfaction and success, nor about the (possible) effects of a body's aesthetic deviance on lifestyle and competitive behavior.

If we are to discuss the relationship, the interaction between biology, medicine and design as one of the core qualities in the self-concept of human health, it is imperative to first look at the *conditio humana*.[1] Any limitation of *conditio humana* can only be provisional and temporary; limitation, for example, to be referring to the fleshly disposition, or, formulated more sharply—limitation to that pre-requisite, which permits the body to become what it then is; that which Psyche contributes to body and vice versa; and that which is not cultural, which is not influenced by lifestyles and socioeconomic conditions or even by sociopolitical differentiations. At the core, a combination of the terms *Design – Medicine* is calling for a discussion and re-thinking in which we seem to be talking on the one hand about a planned manipulation of genetic information and about how and why at the fringes of classical medicine that which is already there and developed physically and psychically is being optimized for more performance and more permanence, and on the other hand about how these (evolutionarily relevant) influences affect the natural environment and ultimately go on to affect humans and irreversibly change humankind. Hence, it is also necessary to suggest possible epigenetic influences; a hypercomplex field in which such influence can only be verified in an exemplary way—and with considerable statistical effort.[2] In the end, we will see that an adjustment or an expansion of the observational dimension is essential.

The *conditio humana*, the problems of the Anthropocenes, the hypercomplex dynamic of the changes occurring on a global scale, and last but not least the foundations and paradigms of the socioeconomic and sociopolitical dependencies, interests and contradictions create a big picture that there is no escaping. The conclusion cannot be that we—because we are doomed to fail in the face of the complexity—simply sit and twiddle our thumbs. Communication, cooperation, discussions on values and perspectives, and especially on acting responsibly—even when this seems to interfere with our accustomed way of life—are essential now.

Necessary elements for this to happen are: solid, united organization; knowledge about these correlations being available to all; and directly addressing the do-ers and "drivers" who have significant influence on the devastating continuation of this development, or who can (help) hinder it.

As difficult as it may be to narrow this topic down here, it is all the more important to understand the issue exactly and consequently and be able to place it in its various interdependencies. In our context, it is, and this must be explicitly differentiated here,

[1] The term "*conditio humana"* is used to refer in general to the conditions of being human and the nature of the human. It is a subject of philosophy, in particular of Philosophical Anthropology, as well as of various sciences such as the social sciences or social psychology. Some, however, reject the term *conditio humana* or the nature of humankind as "essentialistic", saying this term defines the unchangingness of humankind via naturalization and essentialization. (from: Wikipedia (German), Accessed, 15.02.2019).

[2] See chapter "The Key Resources Water, Soil and Intact Ecosystems in Which World Do We Want to Live in the Future?" in this volume, Oexle K, Epigenetics won't do Miracles: Some sobering remarks in response to Prof. Johannes Huber.

now being negotiated that—and why—a doctor/medicine/the medical system will soon be able to define a certain person and create a human, intentionally formed and configured, or a body which is capable of creative and reflective thinking and optimized for something somehow; a living being that perhaps looks like a person but perhaps is not (any longer?) one. From the perspective of philosophical anthropology, we must ask: Has a threshold been crossed which—formulated free of moral consideration for the moment—can be seen as an evolutionarily emergent step? With this as context, I intend here to take a look at this subject from a "dissimilar" yet alert and curious perspective, and perhaps a few special formulations can open the internal discussion somewhat.

2 Possibility and Transgression

1. If we want to understand and define the ***Conditio Humana*** (C.H.), we find ourselves in a dilemma. On the one hand, we cannot observe ourselves from the outside, and most certainly not from the perspective of an alien, and on the other hand, we need a way of measuring the "Humanum" that clearly establishes the border between "Humanum" and "not Humanum". We are in a classic problem of circular reasoning. It seems that Genetics provides sufficient material on this. Is "Human" only one whose genetic information can be repeated through mating (and how else? through artificial reproduction?)? Do only those who repeat themselves belong to the species? Is this so? What then is this "*conditio*"? Is it enough to base our assumptions on a definition of genetic information? How long is this a condition, and what for? And let us additionally ask: What value does the mistake have, the disturbance, the instability, the vulnerability, for the definition of *conditio humana*?

For the definition, do we not also need the co-productive, co-creative combination of the maximal number of varied and differentiated individuals who can ultimately effectively exist with a minimum of regulation? And is therefore the raised (theoretical maximum) variability also a requirement of "Humana"? And what remains as Species is then reduced to its functional basics? We see, in the questions alone, that referring to one individual can never be enough for the "Aufklärung" or "enlightenment" of the *conditio humana*; it will forever remain incomplete. This means, quite practically: the *conditio humana* can be called into question for a number of reasons. Mating is not all of it, the clear boundary to other species will be difficult, intrusion is possible with manipulation and constructiveness, and whether variety or even immunity continues to be enough is a question worth asking. Is someone who is no longer aware of him-/herself, definitely cannot have consciousness of self and feels no pain, but has a body that looks like a human body, is this still a person?

And even pointing out that the individual stands only as an example of C.H. is off the mark, because "*conditio humana*" can never exist in the singular, nor in the "many", but only as sufficiently different co-producers, associated with each other, as qualified coproduction.

The fact that this brings the regulating system, the regulated association, to our attention and with it the production output, in other words initially its physical culture, can indeed be seen then as inflationary for the scientific analysis of the influence of culture on the reproduction of the species. But unfortunately, it is precisely the complicated logic of culture, which holds the mirror humankind created itself up to the associated, reflective humankind. This mirror fatally shows not only what is, but, in the sense of a hermeneutic profit, also what can be. Culture is at times the dramatic image of the enticing or revolting possibilities. Used sociopolitically, it also means that ultimately in choosing partners, or to put it more bluntly—in the coming together of reproductively relevant mating pairs, the distortion in the mirror has a significant and selectively effective influence and indirectly influences the constitution of the communities.

2. This has two consequences. For one, we see that we cannot understand the *conditio humana* without culture and this very excess of possibilities. That which is flawed, the weak, the meditative, the gentle—all are given a function, even if only the resilience of general fitness or the coherence of the associated individuals organized as a group; this is incidentally then honored with awards for problem-solving. The other consequence would be in the effect of selection itself. In the long-term perspective of evolutionary drift and at least as an optional possibility, this goes hand-in-hand with the expansion of characteristics that initially—culturo-historically speaking—increase the influence of culture (a self-enhancing principle). Then the modification and generating of the body and the *conditio humana* itself will be questionable indeed, if and when this principle has also facilitated and carried out the technological, moral and economic invasion into the initial biotic and cultural conditions.

As many as 20 or so years ago, there was a heated discussion in the humanities labeled "Rules for the Human Park," and "The Human Greenhouse."[3] Both texts were heavily attacked from both theological as well as socio-philosophical camps. The emergence of humankind was explained as being a sort of cyclical causality of coincidences and mutations, of performance and of obstacles to reproduction, of external changes in habitat and exploration gains, of pressure to conform and of favoritism. These entwined and interacting attributes were supposed to make it clear what "Human" is, and why. To follow this train of reasoning, it should actually be, what Human "will be."[4]

3. *Conditio humana is a progressing term.* The *conditio* is not and cannot be conclusively defined. For one thing, because it is reflexive—the reflection is its very own and most essential characteristic; for another, because it is itself subject of the

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[3] Both are titles of publications by Peter Sloterdijk [1] Rules for the Human Park. An Answer to Heidegger's Letter on Humanism (*Regeln für den Menschenpark. Ein Antwortschreiben zur Heideggers Brief über den Humanismus*), special edition suhrkamp FFM; and [2] The Human Greenhouse. Key words in historical and prophetic anthropology (*Das Menschtreibhaus. Stichworte zur historischen und prophetischen Anthropologie*), four large lectures, median 5, VDG. Verlag und Datenbank für Geisteswissenschaften. Weimar.

[4] Compare Flusser [3] From Subject to Project. Becoming Human (Vom Subjekt zum Projekt. Menschwerdung). Fischer Taschenbuch Verlag GmbH, FFM.

reflection. This reflection is not free of requirements; although it provides surprises and sees the new—this reflection is productive, humankind is creative. This reflection is, on the other hand, influenced by ideas, by conditions, by the addiction that is fed again and again, that seeks to look into the smallest crack in the schizoid mirror of culture and to decipher, to interpret, what is here and now, what will soon be and what shall be later. This mirror is clouded by values and evaluations. The verdict, the sentences, laws and regulations, coherent communities able to act, states and empires, markets and vacation isles, are anticipatory and normative systems. They are and say how things are to be, what must change, what we have to be on guard against and above all what abilities and prerequisites this "lackful being" (*"Mangelmensch"*) humankind must have or acquire. Either directly or as a prosthesis, as a technical tool, as artificial intelligence or machines able to move optimally and equipped with optimal strength.

4. Inspiring technology! Medicine, in general, has a precondition saturated by experience. This is suffering, pain, the limitations based on the experience of being better, younger, etc. Medicine and health—even when the term "health" is culturally co-founded—are historically sufficiently jointly and more or less suggestively separately definable. No cost or effort is spared in the effort to help people, whether by numbing, healing, correcting or imagining. Holistically speaking, the doctor is also someone who keeps body and soul together, literally. And now though—and this is historically truly new, an emergent situation—the "medical professional" has opened, analyzed and modeled his/her toolbox and subject of work, which is care, far enough that the most advanced medical professionals are in the position to define the human disposition itself, admittedly still on the basis of the hypermodel of the "human individual." The legitimation of medical professionals is, however, as we know, still questionable! The legitimation comes on the one hand from research, which is free and, when talking about fundamental research, also self-referential.

5. On the other hand, in this very subject, we encounter the (still distant?) temptation, in a way a culturally immanent allure, namely, that to improve, optimize, increase, to get the most out of the possibilities. Humankind is a creature whose highest and increasingly most virulent creaturaliness lies in the ability to self-produce. The schism of culture, containing as it does a temptation to something higher—to view us humans as aspiring beings and to make this possible via a few design modifications, to make of us essentially acrobats of the body—and in a further step, acrobats of intended purposes, continuously reaching higher and higher; in this, we seem to have, under certain premises, a quite extensive second legitimation—for (advanced) medicine to evolve, to leave its scope of duties and take tentative steps into the creatural field. Especially when considering limited resources and the logical conclusive competition for them, such a concept of functionality is plausible; it believes that a reduction of at least the socioeconomic effort required for the health of many, if not all, to be the first step to legitimacy, so to speak. The next steps then are increased problem-solving and systematically improved success at this; the last step is then the elimination of the problem itself—most likely a transcendental or ontological utopia. This would however (!) be equal to a shut-down of all development/evolution, since

this, as is well known, needs problem(s) because without them no development is possible. A utopia which is itself dystopic, sufficiently fantasized as paradise.

6. Negation and social challenge, functionality of the disorder? So what would happen if such an optimization step, such a transgression of the health and recuperation system, were not to take place? Can "medicine" remain in its charitable mission, persisting in altruistic benevolence, in active neighborly love?[5] Can research be focused, can it be so tamed as to keep this becoming-like-God, in other words this "intrusion into the evolution with creationistic constructions, with designed optimal beings," definitely confined? What would happen if the social function of the anomaly, the mistake, the miserable disorder, even pain and self-destructive autopoiesis of the cells, had to come to the forefront in favor of a more just society, a society which in its internal organization has not competitively committed itself to economic efficiency, instead being committed to loving support and favorable treatment of the Other? How can society/community learn, how can it learn coherence and "system", that it be as just as possible for everyone? How—without example, without a task, without incentive? What balance do we need between healing, learning and optimizing?

7. Let's go back to where we started: What might we understand design to be? Might Design—understood here as far as possible in the classic sense and not simply reformulating the role of the molecular biologist, the geneticist and the regenerational doctor—also have the task of being like an echo chamber, making "society", the *Sozium,* like an echo chamber which is both visible and experience-able, thinkable, even if with particularly aesthetic sensibility and fascination (at least as a relaxation area for philosophical meditation)? Design as staging of both what can be experienced and common meaning? Design as mediation: we can also claim a special role of design as mediator in conflicts, as moderator and perhaps as a didact, who makes it possible for us to see the design tasks, to be critical and to come to decisions in the best interest of all. It goes beyond design's capacity, however, to ask it to actively contribute qualitatively and with its own perspective to the discussion of meaning itself. This would be misunderstanding design as Art. This role should and must be filled instead by philosophy. Philosophy provides propositions in probably just as provocative formats as we see in the Arts. Philosophy is, however, well advised to fill her theses with the knowledge of the natural sciences and medical sciences. We are thus dealing with three different and complementary terms referring to design in the context of medicine: first that of demiurge in the substantial, second as emissary for negotiations on the interdependencies of civilization and *conditio humana*, and third as functionary of success and beauty, at least for monitoring a healthy or a tolerable difference between being/reality and possibility. In all three areas of function, design

[5] Medicine is the science and teaching of the prevention, detection and treatment of illnesses or injuries in persons and animals. It is carried out by medically trained personnel with the goal of preserving or restoring the health of patients. This refers primarily not only to doctors but also to members of other recognized healing arts—e.g. registered naturopaths in Germany. In addition to human medicine, we have dentistry, veterinary doctors, and in an extended understanding also phytomedicine. In this comprehensive sense, medicine is the teaching about living beings, healthy and ill. (Wikipedia, search term *"Medizin"*).

has its own competence in designing, it has the task of determining the dimensions for that which is holistic, uber-summative and contextual. It can be the means for the integration of the non-expertise of expertise-free persons. It can make popular. Always, however, placed before the background of a story of design as contracted work, as service and—and this seems especially problematic here—with the oft very strong need to express and to have its own intrinsic value. Here design becomes Art. It becomes auto-referential; at least design remains here in the space of interpretation and courtesy held by that vanity in need of income.

8. After considering the separation of roles in our "Bermuda Triangle" between medicine, design and philosophy, it remains to be noted that, first and foremost, philosophy is given the role of formulating the questions that arise out of the seductibility of the physician, the geneticist, etc. Why can Human—THE HUMAN!—not help being driven by his/her nature (his/her potentiality, greed, his/her innate acrobatics) to always conquer the zone that attacks that which is given, that which has become, as inadequate or deficient? Can this be explained on the basis of the normativity of the collective memory, the dependency on rules for cooperative success, the pressure to conform? And even if so, where memory and pressure seem to have been stilled, in the deceptive satisfaction, in idyll and in fullness, practice remains; the constant expectation to practice transgression or go too far remains; the double fitness, to stand firm and to practice transgressing, and to practice practicing. What drives humans to create a sphere in which taking fullest advantage of the "disposition room" of increase (the space of increase possibilities)—generally an increase in efficiency—is celebrated as a general characteristic, as attribute, as their normal way of Being? From this perspective, society and community are practice grounds, a training camp. Here science becomes coach, or trainer, at the very least companion in the process of increased effort. Research, at just the right time, passes the water bottle containing the substances needed.

Humans do this—and have done this since culture emerged in general and now especially with the decoding of DNA! The principle of inadequacy is used, turned on itself, applied. Humankind itself is the gap between reality and possibility; it falls in the gap at any rate, when it has viscerally understood itself as construct. No longer the world, but "The Human as Will and Representation," to freely quote Schopenhauer. Or with Nietzsche: the 'Ubermensch' is an answer to the death of God. "God is dead, God died of commiseration with Mankind." So spoke Zarathustra.[6] His greed for more and higher, especially higher, but also his suffering in efforting, knows only one reference—death, his own death—but this too is put off, for now.

Evolution in nature, then culture, cultural revolution, then co-evolution, the demonstrative and challenging symbolic duplication of the active, producing and reflective Human and now the re-connection of the highest cultural achievement in nature! This is how it is currently, and this is a challenge.

[6] From Thus Spoke Zarathustra (*Also sprach Zarathustra),* p. 181, Anaconda Publishers Cologne, 2004 [5].

3 Philosophy

1. "World" is a word, and a term, for the forming of the infinite, boundless, incomprehensible; a term paradoxical at its core. Philosophy captures this paradox by seeking, on the one hand, to determine what is General and what is the Whole, to label Connection and Proportionality; to name our world and what holds it together, what brings it to substance; and tries to convey that which is beyond the horizon, that which crosses lines, which steps away from that which is safe and known, that which hypothesizes that the "un-whole" has a different "whole", which forms a bridge for those who are open. In doing this, philosophy falls out of radar range so to speak, beneath absolute transcendency. Theologians are responsible for all which happens "above" this plane. Philosophy tests and practices, and shows at least where practice is necessary. Its exploration goes inward *and* outward and inquires into the path in-between. It wants to understand what happens with us and why we have the courage, what keeps us going; what happens with and to us and why we dare to do something, what drives us to leave that which is secure, and also—and this is especially interesting here—what "crossing borders" looks like.

2. Beyond the border is the speculative, in and of itself. But the border cannot be purely abstract, it is not a quasi-mathematical imagination that is there to make it possible to differentiate between that before and behind, that plus and minus, the dimensionalities, and to remain operable both within and between them! The border must be understood as being substantial. It is distinct and unique (*eigen*), it can be taken on or owned (*aneignen*), its characteristics change, we can lose ourselves in (the) border and in (the) world.

3. Why is this so important here in this realm of thought? At its core, philosophy deals with culture. At the same time, culture is the term that is supposed to name for us that which is human in us, at least from one perspective, our all-too-human one; certainly also in order to mark where and when we forget and abandon ourselves. Anthropologically speaking, "culture" marks the emergence of humans, even if that supposedly took 4 million years. What really is important is the ability to look ahead, to project, to *ante*-cipate, to imagine and optimize such action and in doing so to recognize that the border zone has intrinsic value (*eigenwertig*) and that the transgression of what is as the system's dissidence, as expedition, as provocation (which is also always violation), leads not only into a new system (higher complexity), into a new quality, but is of value in and of itself (*selbstwertig*). The transgression of the border creates an expanded, new, World.

4 The Border

4. The border is that zone in which the coherence of the system first becomes hypercritical and then, when its inner balance is thrown off track, collapses, where development begins/or downfall, where the essential nature of humankind is changed. A

border encloses something exactly and is in itself substantially inexact. In the border, something is lit up which chronologically means future, which is that which is new. Philosophy of culture is the realm of negotiations in which it is all about the gap, about what exists in-between, about the option(s) for development. For culture is that mirror which we hold up for ourselves with all of that which we have made into things and have symbolized and which shows us wherein we interpret ourselves, admittedly with the taint of illusion. For the mirror not only shows us in the now and here but also it shows something, and what and how, contains an oft imperceptible disturbance. This disturbance pushes us away slightly; which is shown both entices and repulses. One thing is for sure: what is possible is always vibrating in the background. The mirror generates restlessness, is the temptation to explore. If we look more closely, however, it means that not the mirror in and of itself clouds our view of ourselves by leading us to believe what we could be and do. If this was so, there would be no idyllic spaces and daffodils. Instead, there is something in it, there must be something, that enables us to see, step by step—and certainly not to the same extent for everyone, a distance between a here and now and that which can be. This gap, this border zone, this "hyper-complex," this "dissipative" region which is far removed from balance, this uber-supercharged, sparkly, electrified system field, is where we get the energies of our curiosity, which all in all creates our willingness to believe the promises of betterment, which brings us to leave the safe path for adventure and constantly push limits. Here is the answer to the opening question of being the only creature that refuses to be what it is. Not only the imagined world behind it but also actually and probably the space of and in the border itself is the temptation—but only because it is understood to be, and treated as, a zone, a source of its own.

5 Philosophy of Culture

5. Philosophy of culture is the art of comprehending the temptation and still letting yourself be tempted; it provides the experts for the vibration that emerges when we have completely covered the terrain and can enter new territory. In contrast to moral philosophy, philosophy of culture is not conservative. For morality regulates our behavior so that the existing social structure is stabilized with the least amount of energy expenditure, and challenges that arise out of disruptions and imbalances can be integrated while preserving the structure, or can be paralyzed.

6. Humankind's ethical question in connection with fundamental medicine, in view of its challenges and risks, seems to have been sufficiently discussed, whether for example in conjunction with euthanasia, with abortion, or also with disorders, handicaps or non-specific sexuality. Often the question is then formulated, "Is this permissible?", especially when we think back on a history of fascistic euthanasia and racist mass murder. But is the discussion really closed? Who establishes how, why, adult stem cells may not be used in reproductive medicine, who can prove that the embryonic stem cell already has a soul, or how far we can go with the

"artificialization" of our bodies? Why is the nanobot allowed to transport pharmaceutical biological agents in my blood vessels to boost my performance/productive efficiency, with a minimum of effort and to just the right spot? Why shouldn't I have a microchip implanted that displays my identity, automizes my economic transactions and perhaps even connects my thoughts and typical selections with external, optimized search engines? Why shouldn't I be able to buy a new liver when I've drunk my original one away? What difference is there between artificial hips, heart (pacemaker) and autohaemotherapy before a ski competition, to name a few? We all want to be fit and healthy. Fitness has after all, generally speaking, long been recognized as the social disposition norm.

7. But where are the borders between what medicine calls ***prevention***, in contrast to recognition and treatment of diseases? The term health (or illness) itself certainly also has a generally normative character. The prerogative for interpretation here lies primarily not only with the realm of certified competence but also with the insurance company and only minimally with me as employee with the actual ability to feel and suffer. At the end of the day, we are all negotiating, with differing power of interpretation and above all with differing interests, the possibilities of chemical, biotechnical, genetic and surgical optimizations of an individual's performance profile. Thus we are speaking of ***perfectionizing***. But what is perfect, who determines that, who is involved in the decision process, what paths and steps to that are right and permissible, which can we not afford to take? Has a sufficient goal for all this been determined? What is perfect, complete? What then does "to complete something" mean, particularly when science and research—by their very nature—continuously generate more questions than conclusions? What deficits or shortcomings do we want to fight? Is it truly the "deficit human" (*Mangelwesen*) who in the course of his evolution has supposedly lost everything that his culture could give back to him and could enhance, that "instinctive, overly-driven and cosmopolitan being" (*instinktentbundene, antriebsüberschüssige und weltoffene Wesen*)?[7]

8. Is that "perfect", before the background of an open definition of the *conditio humana*, not limitless? And is the "perfect" here, in our context, an improper term? Above all else a suggestive, tempting one? The aesthetic limits of perfection (from tattoos to a breast job…) could lead us to suspect that the basal construction can also have its limits. Ultimately, we come to the question of what we can truly influence, and what we must take as it is, whether we do so consciously or not. The reference to the statistical value of epigenetic records in our genetic information, which can occur through life circumstances and lifestyles, shows the limits of our sovereignty in this evolutionary process. It also shows, however, how necessary not only moral or moral-philosophic but also culture-philosophic discussion and research is when medicine can do more than heal and to some extent prevent.

Philosophy of culture is, in contrast/comparison to that, lawyer of the more Mephistophelian principle that we have discovered and created them (philosophy ***and*** culture) because morality drives us to boredom.

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[7] Compare Gehlen [4] Der Mensch. Seine Natur und seine Stellung in der Welt [Man. His Nature and Place in the World]. Junker & Dünnhaupt, Berlin.

9. What is more, in the enlightened modernity with its capitalistic and privatistic principles of competition, a reversal of responsibilities has occurred—from society/institution to the individual. Where once we had society, education, the arts, state and local community (for the culture of demands and challenges characterized by continuous striving for a better world), and the system even prescribed betterment as an interventionistic institution, today these systems have, in many cases, been released from their responsibilities. In the late modernity, it is the individuals themselves who have internalized the striving in their function as competitively isolated individuals. The individual now has an economic, quasi-moral and political meaning as "lifestyle subject". This does not make it easier to comprehend humans as beings who are always social. But, in particular, for the intrusive intervention into the *conditio humana*, it is all the more difficult and complicated to negotiate and adhere to suitable, i.e. consensual, binding, non-conservative, standards. Philosophy of culture finds itself here on the threshold of taking on the classic role of moral philosophy.

10. Design is applied in cultural philosophy in the same way that, from the basic medical perspective, genetics is applied in cultural philosophy. However, here a bridge is being built, one that connects the plural-being, the social animal—the uber-summativity, production, communication and creativity animal named human—with the optimized body which has a soul and autoreflexes; a body that experiences desire, stays healthy, lives longer and is free of pain, and furthermore has command over its own regeneration and can ultimately construct its epigenetic conditions in such a way that the effort needed, whether socioeconomic, political-moral or educational-cultural, can be systematically reduced.

6 Looking Ahead

The social habitat has been pacified. Caring is the highest virtue. Preferential treatment of the one who is different from myself is the maxim to act by, and communication is negotiating the best possible sheltering for all.

The integration of the individual is pliant, even with his creative individuality; the realm of domestication is in and of itself latent and, to the greatest possible extent, immanent. There can be no more talk of breeding, inasmuch as it is an un-problematized principle[8] which we follow with joyful curiosity.

In this context, medicine can either become luxurious or limit itself to correcting natural but undesired variability. In this utopia or, better said, dystopia, plastic surgery and applied philosophy of culture join forces and create substance-design-(basic) medicine.

[8] For our context, this means nothing other than the domestication of the wild person.

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Vulnerability is a Talent in the Ecological Crisis

Konrad Oexle

Abstract Due to their autopoietic closure, the biosphere and the social communication systems are alien to each other. This impairs the societal handling of the ecological crisis as Niklas Luhmann has observed. Revisiting his social systems theory, the present article addresses the resonance of environmental problems in social systems, the temptation and danger of resorting to anxiety communication, and the chances provided by violations for interfering with the world beyond the system borders.

Keywords Autopoiesis · Systems theory · Ecological communication · Anxiety · Luhmann

1 Introduction

About a decade before James Lovelock published the "Gaia" [3] concept, Stansilav Lem already presented the idea of a being that covers a whole planet in his novel "Solaris" [2]. Unlike Gaia, however, Lem's living planet does not yield to a rational analysis and has a most disconcerting effect on human observers. Penetrating into the realm of the planet, they cannot understand its processes and utterances. Instead, they themselves experience the most serious irritations and penetrations of their psychosocial existence.

The present paper follows the idea of "Solaris" and starts from the perspective that the biosphere, on the one hand, and the culture, on the other hand, may be fundamentally alien to each other, at least in their origins. For an illustration of that foreignness, consider the relation of the artificial world deployed in a modern computer game to the world in which that computer operates. Incidentally, this relation also has been dealt with in fiction already by Galouye [1], who published his novel "Simulacron-3" 3 years after Lem's "Solaris." The world within the computer knows nothing of the energetic and algorithmic processes that generate it, and conversely,

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these processes in the outside world are indifferent with regard to the meanings and contexts established within the computer world. It is not very likely that the inhabitants of the computer world will ever derive a consistent concept of the generating world. Irritations, violations, and unexplainable deformations of the apparent reality may initiate the development of such a concept, and once on the funnel, the inhabitants of the computer world may possibly try to systematically seek out or provoke similar irritations in order to test and improve their concept.

2 Luhmann's Analysis

Of course, such thoughts have precursors in the history of philosophy since Plato's allegory of the cave. Constructivist systems theory is considered here as one of the more recent generalizing approaches in this tract. According to this theory, the system of the biosphere and the social system are categorically different at the level of the autopoietic[1] operations with which the systems maintain and continue themselves. In the case of society, these operations are communications, which relate to each other. They function as distinctions along system-specific expectations. To be connectable ("anschlussfähig" in German) within the social system, communications about the mechanisms and phenomena of the natural environment do not need to be precise or realistic. Historically, even primitive or magical distinctions proved to be connectable. And today most communications are still rather undifferentiated: "What we know about the stratosphere is similar to what Plato knows about Atlantis: one has heard of it" [6]; citations translated by the author). It is true that in modern societies functionally differentiated subsystems have developed, such as politics, law, economics, or science. But even these subsystems may be indolent to hazards arising from the natural environment, because their autopoietic operations in form of specific political, juridical, economic, or scientific communications are not informed by such hazards, as long as the hazards are not translated (or even not translatable) into the communication code of the specific subsystems. What has no price does not exist for the economy, and the legal system is not triggered when the

[1] "Autopoiesis" is the recursive self-generation and maintenance of systems. "The product of their organization (is) themselves, that is, there is no separation between the producer and the product. The being and the doing of an autopoietic unit are inseparable, which constitutes its specific type of organization [7]." Such systems, therefore, consist of the continuous operations that keep them running. A living system exists as its specific, self-regulating, and self-generating organization of biochemical operations, but not as the substances and structures of the internal or external environment that are built up and broken down in the process. What an autopoietic system "knows" about its environment is identical to the self-constructed organization by which it distinguishes itself from the environment. As accidental as this distinction has arisen, as selective is a system's "knowledge" of its environment. According to Nikolas Luhmann, the autopoiesis of social systems runs through communications. The specific nature of such communication determines the perceptions and constructions of reality in social subsystems. Science does not judge what is lawful, and justice does not decide what is scientifically right.

principle of polluter liability fails in complex environmental circumstances as Niklas Luhmann has emphasized [4–6].

Already in 1986, the year of the Chernobyl reactor accident and the first SPIEGEL cover-picture depicting the "climate catastrophe," Luhmann [4] analyzed from the perspective of systems theory whether social systems are able to meet the ecological challenge, considering that "the primary goal of autopoietic systems" is the "continuation of autopoiesis without regard to the environment." because "the next (autopoietic) step typically is more important than the consideration of a future that will not be reached by a system if its autopoiesis is not continued" [4]; citations translated by the author). According to Luhmann, society can "only react to environmental problems under the very limited conditions of its own modes of communication. This also applies to environmental problems that it has itself triggered." On the one hand, Luhmann saw the possibility of insufficient "resonance," so that society remains inattentive to the ecological harms. On the other hand, he saw the danger that ecologically activated politics might generate too much "resonance" in other subsystems such as law or economics, thereby impairing their autopoiesis, that is, function so that these subsystems are even less able to solve the problems posed to them by the political system. "Nothing hampers the politicians, as one can read in the newspapers, to demand and to promise an ecological adaptation of the economy; they are not obliged to think and act economically since they do not operate within the system that ultimately fails to meet their demands." As a result of such failure, anxiety communications ("Angstkommunikationen" in German) may become dominant with inflationary, selective, and small-scale moralizations, because "[anxiety] is the principle that does not fail when all principles fail." Then, there is hardly a way back since "scientific attempts to explain the complicated structure of risk and safety issues just fuels anxiety with new alarms."

3 Conclusion

One generation after Luhmann's book on "ecological communication," it is still the question of whether and how the extreme he pointed out can be avoided. Specifically, efforts such as a workshop entitled "Violated Earth, Violent Earth" must ask whether they efficiently shake up a public that still perhaps is not sufficiently alarmed or whether they succumb already to the temptation of too much anxiety communication. The latter would be counterproductive. Instead, such efforts must have the goal to offer ecological communications to society's functional subsystems so that these subsystems successfully include the environmental topics in their respective autopoieses.

At the most abstract level, the term "violation" that sounds in the conference title, can be regarded as a system-theoretical concept. For Luhmann, "violations" of the world take place already by the communicated distinctions/observations with which systems demarcate themselves autopoietically, and on which the world reacts with distinction-typical irritations: "It must be assumed that the world (whatever that is) tolerates the making of distinctions and that depending on the specific distinction by which it is violated, it irritates differentially the observations and descriptions evoked thereby. All such irritation of observation is therefore always relative to the distinction, which underlies the observation. The world thus appears as involved invisibility; or as an indication that it can be inferred only recursively" [5]; citations translated by the author). From this perspective, the circle of “violation” and “violent reaction,” as stated in the title of the workshop, would be linked to the process of world injury and reactive irritation of society by the world, which society has always used to infer the world. Even that title can then be understood as a scientific communication, and not as a communication of anxiety.

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From Anthropocene to Artificial Intelligence? Challenges of Machine Learning for Science, Life, and Society

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Abstract In a complex dynamical system of natural and civilizational influence, which is sensible to local perturbations and may undergo chaotic destabilization due to nonlinear interactions, artificial intelligence (AI), data mining, and modern sensor technology may provide the urgently needed early monitoring systems. However, these tools, when powerful and self-organizing, may themselves pose ecological and ethical problems. Therefore, we need more global governance of an AI-supported socioeconomic and Earth system to keep the balance of the whole system.

Keywords Complex systems · Artificial intelligence · Internet of things · Governance

1 Introduction

The Anthropocene is a proposed epoch dating from the commencement of significant human impact on the Earth's geology and ecosystems, including anthropogenic Climate Change. The most recent period of the Anthropocene has been referred to as the emergence of a socioeconomic and Earth system since the industrial revolution. Obviously, during the Anthropocene, human abilities have been supported and replaced by machines step by step up to machine learning. Therefore, the question arises whether we actually live in the dusk of the Anthropocene followed by a new epoch of Artificial Intelligence (AI).

In the first part, we consider the complex and highly nonlinear dynamics of violated and violent Earth. Increasing complexity and Big Data in, e.g. life sciences and ecology need the support of machine learning. Learning algorithms (e.g., deep

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learning) are efficient tools of pattern recognition in billions of data, which can be applied for monitoring and supervising ecological systems. But, statistical correlations of data must not be confused with causal laws. Without a clear distinction of causes and effects, we do not get a deep understanding of science. Only causal understanding allows accountability and responsibility.

2 Complex Dynamics of Violated and Violent Earth

The Earth is a highly complex dynamical system, which is driven by a variety of natural causes. Astronomical, geological, and biological factors are not always controllable by humans. For example, mathematical models demonstrate that the dynamics of the planet Earth causes changing conditions of climate. In this sense, Earth is violent. But, we must also consider all factors of human civilization (e.g. population growth, growth of industry, pollution) connected by nonlinear feedback causal loops which are highly sensible with respect to local perturbation leading to global effects of instability and chaos. In this sense, Earth is violated. The Anthropocene is the epoch of a violated Earth that is caused by significant human impact (anthropogenic) on Climate Change.

The reason is that, in the age of globalization, the Earth system grows together with human civilization. Climate and ecological systems can no longer be separated from human civilization, but depend on industrial growth and energy policies. Global communication networks and infrastructures as well as financial dependencies of banks and states are driven by nonlinear dynamics of complex systems. One of the main insights of nonlinear dynamics is the emergence of systemic risks, which are caused by the interactions of many factors and players in the whole system of Earth [18]. The emergence of systemic risks from complex systems dynamics is a challenge for control tasks in engineering sciences as well as regulation and governance in social systems. We need modeling in systems science with early warning systems in the technical and natural sciences as well as in economics and politics. In higher education, the awareness of global networks must be supported by interdisciplinary courses of systems science. Systems science offers a common language of natural, engineering, economic, and social sciences, which is necessary to communicate with different disciplinary backgrounds of education.

Interdisciplinary courses of systems science must start with basic concepts of modeling: Models are formal descriptions of systems in different sciences. They refer in particular to natural systems in astronomy (e.g., planetary systems), physics (e.g., atomic systems), chemistry (e.g., molecular bonds), and biology (e.g., cellular networks), but also to social systems in economics (e.g., financial markets), sociology (e.g., social networks), and political science (e.g., administrative organizations). When engineers analyze a technical system to be controlled or optimized, they also use a mathematical model. In mathematical analysis, engineers can build a model of the system as a hypothesis of how the system should work, or try to estimate how an unforeseeable event could affect the system. Examples are extreme events and risks emerging in complex systems. Similarly, in control of a system, engineers can try out different control approaches in simulations. Simulations are often represented by computer programs and tested on computers. In the natural sciences, the validity of models is tested by derived explanations or predictions, which are confirmed or falsified by observations, measurements, and experiments. A hypothetical model is a more or less appropriate mapping of reality.

A mathematical model usually describes a system by a set of variables and a set of equations that establish relationships between the variables [9, 19]. A dynamical system is characterized by its elements and the time-depending development of their states. The states can refer to moving planets, molecules in a gas, gene expressions of proteins in cells, excitation of neurons in a neural net, nutrition of populations in an ecological system, or products in a market system. The dynamics of a system, i.e., the change of system states depending on time, can mathematically be described by, e.g., time-depending differential equations. In a more intuitive way, a conservative system is "closed" with respect to external influences and only determined by its intrinsic dynamics. A dissipative system can be considered to be "open" to external influences, e.g., air or other material friction forces. Models of conservative and dissipative systems can also be applied in ecology and economics.

3 Case Study: Conservative and Dissipative Systems in Ecology

At the beginning of the twentieth century, fishermen in the Adriatic Sea observed a periodic change of numbers in fish populations. These oscillations are caused by the interaction between predator and prey fish. If the predators eat too many prey fish, the number of prey fish and then the number of predators decreases. The result is that the number of prey fish increases, which then leads to an increase in the number of predators. Thus, a cyclic change of both populations occurs. In 1925, the Italian mathematicians Lotka [8] and Volterra suggested a dynamical model to describe the prey and predator system. Each state of the model is determined by the number of prey fish and the number of predator fish. So the state space of the model is represented by a two-dimensional Euclidean plane with a coordinate for prey fish and a coordinate for predator fish. The observations, over time, of the two populations, describe a dotted line in the plane. Births and deaths change the coordinates by integers, a few at a time. To apply continuous dynamics, the dotted lines must be idealized into continuous curves. Obviously, the Lotka-Volterra model is closed to other external influences of, e.g., temperature or pollution of the sea. If these external forces of "ecological friction" were added to the model, its dynamics would change the cyclic behavior.

The Lotka-Volterra equations are a simple, but still a nonlinear formal system, which is fine for educational tasks. Students learn to model the interaction of prey and predators in zoology as well as economics. Modeling in this way is a top-down procedure from mathematical equations to applications by appropriate interpretations of variables. In a bottom-up approach, we start with a sequence of measurements and ask what the data themselves can tell us about the laws of dynamics. Sequences of data are called time series. Time-series analysis is used to find types of appropriate equations fitting the data, or to compare the predictions of mathematical models to measurements made in the field of research.

In an ideal case, time-series analysis delivers a computer program providing a mathematical model fitting the measured data. But these data-generated models have a severe shortcoming because they work without any understanding of the physical system. In practice, model building is combined with time-series analysis. Model building is based on knowledge of a physical system, while time-series analysis can be used to detect features of a system, inspiring model building.

4 From Deterministic to Stochastic Models

For a better understanding of basic scientific concepts, it is often inspiring and motivating to learn more about the historical context of scientific discoveries and developments. During the centuries of classical physics, the universe was considered a deterministic and conservative system. A system is said to be deterministic when future events are causally set by past events. In 1814, the astronomer and mathematician P.S. Laplace assumed the total computability and predictability of nature if all natural laws and initial states of celestial bodies are well known. The Laplacean spirit expressed the belief of philosophers and scientists in determinism and computability of the world during the eighteenth and nineteenth centuries. In this historical period, mechanics was a universal paradigm of research. Mechanical machines dominated the first period of industrialization. Laplace was at least right about linear and conservative dynamical systems. In general, a linear relation means that the rate of change in a system is proportional to its cause: Small changes cause small effects while large changes cause large effects.

At the end of the nineteenth century, H. Poincaré discovered that celestial mechanics is not a completely computable clockwork, even if it is considered a deterministic and conservative system. The mutual gravitational interactions of more than two celestial bodies (‘Many-bodies-problem’) can be illustrated by causal feedback loops analytically represented by nonlinear equations, which are sensible with respect to tiny perturbations. Causes and effects are no longer proportional: Tiny deviations in digits behind the decimal point of measurement data may lead to completely different forecasts. This is the reason why attempts to forecast weather fail in an unstable and chaotic situation. In principle, the wing of a butterfly may cause a global change of development (“butterfly effect”). The butterfly effect is an important insight, in order to understand the nonlinear dynamics in nature, economy, and society, although it is only a metaphor for the high sensibility with respect to tiny perturbations in well-defined intervals: The wing of a butterfly does actually not change the weather or climate.

Typical phenomena of our world, such as weather, climate, the economy, and daily life, are much too complex for a simple deterministic description to exist. Even if there is no doubt about the deterministic evolution of, e.g., the atmosphere, the current state whose knowledge would be needed for a deterministic prediction contains too many variables in order to be measurable with sufficient accuracy. Hence, our knowledge does not usually suffice for a deterministic model. Now, statistics and probability theory come in. They also deliver basic knowledge for interdisciplinary modeling in systems science.

Actually, very often a stochastic approach is more situated. Ignoring the unobservable details of a complex system, we accept a lack of knowledge. Depending on the unobserved details, the observable part may evolve in different ways. However, if we assume a given probability distribution for the unobserved details, then the different evolutions of the observables also appear with specific probabilities. Thus, the lack of knowledge about the system prevents us from deterministic predictions, but allows us to assign probabilities to the different possible future states. It is the task of a time-series analysis to extract the necessary information from past data.

5 Example: Power Laws and Risks

In the simplest case of statistical distribution functions, a Gaussian distribution has the well-known shape of a bell with exponential tails situated symmetrically to the far left and right of the peak value. Extreme events (e.g., disasters, tsunamis, pandemics, worst cases of nuclear power plants) occur in the tails of the probability distributions [3]. Contrary to the Gaussian distribution, probabilistic functions $p(x)$ of heavy tails with extreme fluctuations are mathematically characterized by power laws, e.g., $p(x) \sim x^{-\alpha}$ with $\alpha > 0$. Power laws possess scale invariance corresponding to the (at least statistical) self-similarity of their time series of data. Mathematically, this property can be expressed as $p(bx) = b^{-\alpha} p(x)$ meaning that the change of variable x to bx results in a scaling factor independent of x while the shape of distribution p is conserved. So, power laws represent scale-free complex systems. The Gutenberg-Richter size distribution of Earthquakes is a typical example of the natural sciences. Historically, Pareto's distribution law of wealth was the first power law in the social sciences with a fraction of people presumably several times wealthier than the mass of a nation [10].

An important part of the modeling process is the evaluation of an acquired model [19]. How do we know whether a mathematical model describes the system well? This is not an easy question to answer. We must become aware of these methodological needs and failures. Usually, the engineer has a set of measurements from the system, which are used in creating the model. Then, if the model was built well, the model will adequately show the relations between system variables for the measurements at hand. The question then becomes: How do we know that the measurement data is a representative set of possible values? Does the model describe well the properties of the system between the measurement data (interpolation)? Does the model describe well events outside the measurement data (extrapolation)? Extreme events in anthropogenic systems (e.g., urban system) initiate global cascades of nonlinear effects. We need policies of early warning systems and crisis management. How should we manage the nonlinear dynamics in a complex Earth system? At this point, artificial intelligence (AI) comes in.

6 Machine Learning and Neural Networks

Modern AI is mainly machine learning, which is based on artificial neural networks and learning algorithms [12]. Neural networks are simplified models of the brain, which can also be considered as complex system. The brain consists of neurons as elements of a complex system interacting through synaptic signals. Mathematically, their interactions are modeled by nonlinear dynamics. In 1943, W. S. McCulloch and W. Pitts proposed a first model of a technical neural network [13]. The synaptic interactions are weighted by numbers indicating their neurochemical strength. A major limitation of the McCulloch-Pitts nets was the assumption that the weights were fixed forever. Thus, a decisive performance capability of the brain is excluded from its evolution in phylogeny. Learning is made possible by modifications of the synapses between the neurons. Therefore, it requires variable synapse weights. The strength of the connections (associations) of neurons depends on the respective synapses. From a physiological point of view, learning is therefore a local process. The changes of the synapses are not caused and controlled globally from the outside, but happen locally at the individual synapses by changing the neurotransmitters.

According to this concept, the American psychologist F. Rosenblatt built the first neuronal network machine at the end of the 1950s, which was supposed to accomplish pattern recognition with neuron-like units. However, due to its slowness and limited learning ability, in which only the synaptic weights can be changed to the output layer, the perceptron proved to be practically unusable. In addition, there was a serious mathematical limitation:

The perceptron learning algorithm (1950) begins with a random set of weights and modifies these weights according to an error function to minimize the difference between the current output of a neuron and desired output of a trained data pattern (e.g., letter sequences, pixel image). This learning algorithm can only be trained to recognize supervised learning patterns that are “linearly separable". In this case, the patterns must be clearly separable by a straight line. M. Minsky, leading AI-researcher and S. Papert proved in 1969 that the perceptron would fail if the patterns were only separated by curves (“nonlinear”) [15, 16].

Initially, Minsky and Papert regarded the proof as to the fundamental limit of neural networks for AI research. The solution to the problem was inspired by the architecture of natural brains. Why should information processing only run in one direction through the superimposed layers of networked neurons? D. E. Rumelhart, G. E. Hinton, and R. J. Williams proved in 1986 that feedback information flows (backpropagation) between input, intermediate, and output layer with suitable activation and learning algorithms also allow nonlinear classifications. In 1989, K. Hornik, M. Stinchcome, and H. White proved that under appropriate conditions also feedforward-architectures can be used [6, 17].

A nonlinear function of input variables is determined by optimizing the weights of the function y(W,X) with the weight vector W to be calculated, the vector X of the known inputs, and the known output y. A (feedforward) neural network with 3 layers of input neurons, middle ("hidden") neurons and output neurons is determined by the output function

$$y(Z, W, X) = o(Z \cdot h(W \cdot X))$$

with input vectors X, weight vectors W between the input layer and hidden neurons, activation function h of hidden neurons, weighting vector Z between hidden neurons and output neurons and activation function of the output neuron. With an output neuron, individual numerical values can be predicted.

A feedforward neural network with 3 layers and two output neurons is determined by the output

$$y_1(Z_1, W, X) = o(Z_1 \cdot h(W \cdot X))$$

$$y_2(Z_2, W, X) = o(Z_2 \cdot h(W \cdot X))$$

function with weight vectors and between the hidden neurons and the two output neurons.

Multiple output neurons can be used for classification tasks. Neural networks learn to predict to which class (corresponding to the number of output neurons) an input belongs (e.g., faces, ecological patterns of landscape, molecular and cellular patterns in medicine) [1].

Multilayer neuron networks are used in visual perception. They can be simulated on the computer. Learning processes with multi-layered neural networks are also referred to as "deep learning". What is meant here is that a step-by-step "deeper" understanding of a factual situation (e.g., a picture) develops after first only individual building blocks, then clusters, and finally the whole are recognized.

At the beginning of the 1980s, physicist J. Hopfield developed a single-layer neural net, which can be applied to the model of self-organizing materials (spin glass model) [5]. A ferromagnet is a complex system of dipoles, each with two possible spin states up (↑) and down (↓). The statistical distribution of the up and down states can be specified as the macrostate of the system.

When the system cools down to the Curie point, a phase transition takes place in which almost all dipoles spontaneously jump into the same state, and therefore a regular pattern emerges from an irregular distribution. The system thus changes into a state of equilibrium, in which an order is organized independently. This order is perceived as the overall magnetic state of the ferromagnet.

Hopfield analogously described a network of a single layer in which binary neurons are completely and symmetrically networked. It is therefore a homogeneous neural network. The binary state of a neuron corresponds to the two possible spin values of a dipole. The dynamics of the Hopfield system is modeled exactly on the spin glass model of solid-state physics. The energetic interaction of the magnetic atoms in the spin glass model is now interpreted as an interaction of binary neurons. The distribution of the energy values in the spin glass model is understood as the distribution of the 'computing energy' in the neuronal network.

According to the modeling of complex dynamical systems, we can clearly imagine a potential mountain range above the state space of all possible binary neurons [5]. If the system starts from an initial state, it moves downhill in this potential mountain range until it gets stuck in a valley with a local minimum. If the starting state is the input pattern, then the reached energy minimum is the response of the network. A valley with a local energy minimum is therefore an attractor to which the system moves.

The recognition process is a phase transition to a target attractor, as we have already observed with ferromagnets. It should be emphasized that this phase transition happens without central program control by self-organization. Hopfield systems can also be used for cognitive tasks. In the potential mountains, the lowest energy state represents an optimal solution.

An optimization problem, such as the search for an optimal travel route at is also possible with a Hopfield system: In a Hopfield system, the different distances between cities and the order in which they are visited are taken into account by corresponding synaptic weights. In fractions of a second, the computing energy sinks into a stable, low-energy state that represents the shortest route.

A neural network can thus constantly decide between millions of possible answers, because it does not have to check the answers one after the other. Nor does it assume that every possible answer is true or false. Each possibility rather has its synaptic weight, which corresponds to the strength of the assumption that connects the system with each possibility. They are processed in parallel.

Hopfield systems work in parallel, but deterministically, i.e., every neuron is indispensable for character recognition. However, living nerve cells hardly behave like determined planetary systems, and even with corresponding technical network models, major disadvantages occur. If we imagine a recognition process or a decision-making process in the sense of Hopfield as energy reduction, then the learning process can get stuck in a valley that is not the deepest in the whole network.

T. J. Sejnowski and G. E. Hinton, therefore, proposed a procedure to lead the network to ever deeper valleys [4]. If a sphere has reached a valley in the energy mountains, then the obvious and descriptive suggestion is to shake the whole system a little such that the sphere can leave the valley to take lower minima. Strong or weaker shaking movements change the probability of a sphere being located as with a gas molecule, whose collisions are influenced by pressure and temperature changes.

Therefore, Sejnowski and Hinton named their probabilistic network "Boltzmann machine" after the founder of statistical mechanics and thermodynamics. It is remarkable that John von Neumann had already pointed out the connection between learning and cognitive processes to Boltzmann's statistical thermodynamics. The problem of finding a global minimum in the network and avoiding secondary minima occurs physically in the thermodynamics of crystal growth. In order to give a crystal a structure that is as free of defects as possible, it must be cooled slowly. The atoms must have time to find places in the lattice structure with minimal total energy. At sufficiently high temperatures, individual molecules are able to change their state in such a way that the total energy increases. In this case, local minima can still be left. As the temperature drops, however, the probability of this happening decreases. This procedure is also clearly described as "simulated annealing or cooling".

Probabilistic networks are experimentally very similar to biological neuronal networks. If cells are removed or individual synaptic weights are changed by small amounts, Boltzmann machines prove to be the right choice as fault-tolerant toward smaller disturbances such as the human brain with smaller accident damages. The human brain works with layers of parallel signal processing. For example, internal intermediate steps of neuronal signal processing that are not in touch with the outside world are taken between a sensory input layer and a motor output layer. In fact, the representation and problem-solving capacity of technical neural networks can also be increased by interposing different layers with as many neurons as possible that are capable of learning. The first layer receives the input pattern. Each neuron of this layer has connections to each neuron of the next layer. The series of executive transactions one after the other continues until the last layer is reached and gives off an activity pattern.

7 Machine Learning in Ecology

In ecology, machine learning enables pattern recognition in meteorology. For example, clouds can be classified in characteristic forms of "gravel, fish, and flower", which are correlated with special constellations of weather. AI can also support early warning systems of tsunamis. For example, the spreading wave of a tsunami after two hours can be measured according to satellite-based altimetry. A colored pattern of waves illustrates the spreading wave in an AI-based predictive model. The spread and height of the wave can be related to the overflying degrees of latitude. In the next step, the AI-based predictive model can be compared with the measurements of the satellite.

In agriculture, by 2050, farmers must produce more food, on less arable land, and with lower environmental impact to feed the world's rapidly growing population. AI can help people efficiently monitor the health of farms in real time. In the next two decades, demand for freshwater is predicted to dramatically outpace supply. AI can help people model Earth's water supply to help us conserve and protect freshwater. Species are going extinct beyond the natural rate by orders of magnitude. AI can help people accelerate the diversity, monitoring, and protection of biodiversity across our planet. Increasingly variable climates threaten human health, infrastructure, and natural systems. AI can provide people with more accurate climate predictions to help reduce the potential impact on communities.

In Earth science, advances in AI are needed to collect data where and when it matters, to integrate isolated observations into broader studies, to create models in the absence of comprehensive data, and to synthesize models from multiple disciplines and scales. Intelligent systems need to incorporate extensive knowledge about the physical, geological, chemical, biological, ecological, and anthropomorphic factors that affect the Earth system. A new generation of knowledge-rich intelligent systems has the potential to significantly transform geosciences.

But, without more explanation, big neural networks with large statistical training data (Big Data) are black boxes. Statistical data correlations do not replace explanations of causes and effects. Their evaluation needs causal modeling for answering questions of accountability and responsibility [12]. We need more explainability, accountability, and governance of machine learning and Big Data to master the increasing complexity of our Earth system!

8 Internet of Things in Ecology

Metaphorically speaking, the nervous system of human civilization is now the Internet. Up to now, the Internet has only been a ("stupid") database with signs and images whose meaning emerges in the user's mind. In order to cope with the complexity of the data, the network must learn to recognize and understand meanings independently. This is already achieved by semantic networks that are equipped with expandable background information (ontologies, concepts, relation, facts) and logical reasoning rules in order to independently supplement incomplete knowledge and draw conclusions. For example, people can be identified, although the data entered directly only partially describe the person. Here again, it becomes apparent that semantics and understanding of meanings do not depend on human consciousness.

With Facebook and Twitter, we are entering a new dimension of data clusters. Their information and communication infrastructures create social networks among millions of users, influencing and changing society worldwide [2]. Facebook was created as a social network of universities such as Harvard in 2004. Social and personal data are always online. Data is by no means just text, but also images and sound documents.

Complex patterns and clusters are created in networks by locally active nodes. If people are influenced by the activity of their network neighbors, the adaptation to a new product or innovation can spread cascadingly in the network [7]. The spread of an epidemic disease (e.g., tuberculosis) is also a form of cascading pattern formation in the network [14]. The similarity between biological and social patterns leads to interdisciplinary research questions. The local activity and mutual influence of the net nodes (whether customers or patients) can in principle be described by diffusion-reaction equations. Their solutions correspond to patterns and cluster formations. If the parameter spaces of these equations are known, the possible cluster formations can be systematically calculated.

Self-organizing disciplines, applications, and stakeholders achieve offer and demand for new services and integrated solutions. But, while the classic Internet only supports communication between people in global computer networks, sensor technology opens up new possibilities for the future. A new dimension of communication: commodities, products, goods, and objects of all kinds can be equipped with sensors to exchange messages and signals. The Internet of persons transforms into the Internet of Things.

In the Internet of Things (IoT), physical objects of all kinds are equipped with sensors (e.g., RFID chips) to communicate with each other. This enables automation and self-organization of ecological and societal systems.

Hidden RFID and sensor technology creates the Internet of Things that can communicate with each other and with people. For the Internet of Services, offers and technologies in the area of online commerce or online services and the media industry will be comprehensively expanded.

In the industrial Internet (German: Industry 4.0), machines and products are equipped with sensors to communicate with one another by codes. Thus, in the industrial Internet, there is not only man-to-man and man-to-machine communication, but also machine-to-machine communication, in order to realize the automation of production and trade, step by step. In symbiosis with nature, we can also consider an agricultural Internet (German: Agriculture 4.0). In this case, agricultural machines are equipped with sensors as self-learning (automotive) cars. Neural networks may enable self-learning abilities, in order to act with certain degrees of autonomy. Animals and the growth of plants can be supervised and coordinated with the support of AI methods. The Internet of Things can be applied to complex ecological systems. In forests and national parks, the care of plants and animals can be supported by a network of sensor networks and drones. Neural networks can be trained to react in safety-critical situations of ecological systems autonomously. Ecological data can be stored to improve the efficiency of learning algorithms.

Increasing computational power and acceleration of communication need improved consumption of energy, better batteries, miniaturization of appliances, and refinement of display and sensor technology. Under these conditions, intelligent functions can be distributed in a complex network with many multimedia terminals. Together with satellite technology and global positioning systems (GPS), electronically connected societies are transformed into cyberphysical systems. They are a kind of symbiosis of nature and human society. Communication is not only realized between human partners with natural languages, but with the things of this world. Cyberphysical systems also mean a transformation into an Internet of Things. Things in the Internet become locally active agents [11].

But, improved consumption of energy may also influence environmental conditions. Thus, we must pay attention to avoid a circulus vitiosus with better care and protection of nature at the expense of pollution of the environment. The problem is solvable with the application of sustainable energy production. In the end, we need an ecological, economic, social, legal, and ethical roadmap of standards for a sustainable Internet of Things:

Which ecological, ethical, and legal standards should be considered for embedded systems (e.g., mobility infrastructures, smart cities)?

Which ecological, ethical, and legal questions do arise with intelligent delivery systems (e.g., energy systems)?

Which ecological, ethical, legal, and social standards are necessary for the increasing automation of the labor world (e.g., Industry 4.0)?

Which ecological, ethical, and legal standards should be considered for applications of intelligent infrastructures to support the violated and violent Earth?

Which ethical and legal standards are demanded for the digital dignity of humans and a sustainable Earth system?

9 Conclusions

AI and machine learning can be used as a service system for a global transformation to a sustainable society on Earth: Our Earth system is a complex dynamical system which does not only depend on natural factors (such as climate, water, energy), but also on nearly all influences of human civilization (e.g., industrial growth, population growth). Therefore, the causal ("nonlinear") interaction of all these factors is highly sensible with respect to local perturbations, potentially leading to global destabilization and chaos. Hence, we need global monitoring and early warnings systems to keep the balance of the whole system. Modern machine learning, data mining, and sensor technology can provide such monitoring, e.g., predictive analytics of climate models and early warning systems of Tsunamis; AI can help to monitor and protect agriculture, water, and biodiversity. But, we do not only need more causal explainability and computability of models. We also need more political responsibility to realize these scientific insights.

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Ecology: A Key Resource

The Key Resources Water, Soil and Intact Ecosystems: In Which World Do We Want to Live in the Future?

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Abstract In the Anthropocene era, humans have become one of the most important factors influencing the Earth system. The achievements of the Anthropocene have brought us enormous prosperity. There are increasing signs that the unintended side effects are endangering this prosperity and even our civilization. The current situation, such as the separation of humans from their environment, can only be understood if approached from a cultural-psychological standpoint. New utopias have to emerge with answers to questions like "In which world do we want to live? What steps are necessary?". The urban idea of protection (city as a protected demarcated habitat) needs to be extended to the whole environment, but do we need to have already answered all such questions before moving into a sustainable Anthropocene? We think not. Far more important is the question of how to achieve such broad resonance that will set the whole of humanity vibrating for the-as yet-undiscovered utopia of the "Sustainable Anthropocene. Maybe it is that of a "Second Enlightenment," the exit of man from his self-inflicted limitation and demarcation. It would end our tyranny over the environment and thus dissolve our self-imposed isolation.

Keyword Anthropocene · Civilization · Ecosystem · Psychology · Culture · Sustainable life

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1 An Overview: What is the Problem?

During the Anthropocene period, the most recent epoch of the Quaternary (ice age), Man became one of the most important factors influencing biological, geological and atmospheric processes on Earth. He thus occupies a prominent position and must assume responsibility for the further joint development of society and the environment. It is, therefore, worthwhile first of all to deal with the nature of this increasingly important influencing factor, the human being.

1.1 Three Essential Theses on the Environment

A stable environment is essential for our survival. What's more, the environment is our *second skin*. In the Anthropocene, we were responsible for its care. "Subdue the Earth!"—We have done that—Now became the obligation: "Take care of her too!".

With the achievements of the Anthropocene, we have considerably improved our quality of life over the past two hundred years. Now, however, the side effects are becoming increasingly apparent: Our environment is changing on a broad front in a worrying way (Climate Change, extinction of species, land consumption). Science assumes that the carrying capacity of the (global) environment has already been exceeded and that the continued existence of our civilization will ultimately be endangered (Table 1).

With our activities, which are initially legitimate, we burden all parts of the environment:

Table 1 Human intervention with the key resources

Water	Quantity	Floods and droughts; interventions (e.g. irrigation and drainage, storage, watercourse development)
	Quality loss through pollution	Groundwater, rivers, lakes wetlands, oceans through intake of, e.g. nutrients incl. manure, pesticides, plastics, cooling water
Soil	Quantity	Sealing, erosion due to the lack of plant cover, compaction
	Quality loss	Over-fertilizing, salinization, loss of micro-biota and biodiversity
Air	Quality loss	Due to pollution, temperature rise, deterioration of natural air circulation
Animated nature	Quality loss	e.g. deforestation, urbanization, industrial agriculture, industrialization, roads and railroad tracks, excessive tourism
	Loss beauty	Recreation, homeland feeling

Beyond the purely scientific consideration of the damages, it is above all in the question how long a "continue like this" of our cultural development will contribute to maintaining or increasing satisfaction and well-being.

In order to develop concrete utopias of a sustainable Anthropocene, we must go beyond what we already know. These utopias should be so plausible and attractive that they are accepted and implemented.

1.2 Approach from the Perspective of Cultural Psychology of the Anthropocene Culture

From the very beginning, the progress of our cultural history has been linked to a demarcation from the natural environment. According to the philosopher Peter Sloterdijk, this symbolically means "peeling safe spaces out of a threatening, dangerous, uncomfortable environment". Its first social and ecological consequence was "interior sanctification and resentment of environment" [22]. Remarkably, this prearchaic attitude is still widespread today, as are current political statements of the type: "The environment is the classic enemy of the economy" [25].

The Bible takes an utilitarian view on our relationship to the environment by saying "Subdue the Earth"! In our cultural history, this has been implemented very successfully by the achievements of the intellect with the help of many technologies. We actually profit enormously from this progress. For a large part of the world's population, it shows itself in the improvement of living conditions up to the significant extension of our average lifetime. Meanwhile, however, doubts are growing about the way in which we wrest these successes from the (surrounding) world and what we are doing this for. The environmental encyclical Laudato si' of Pope Francis criticizes the fact that the technology with which the Earth's resources are made available is ultimately "neither about benefit nor welfare, but about domination", and that questioning it has become "culturally illegal" [5].

The environment has become: An external, separate and yet immediate part of us that surrounds and protects us like a second skin.

In fact, our previous model of thinking about the environment can no longer be maintained in this way, for we have in fact appropriated the "separate" environment through anthropogenic over-shaping: "For the boundary between "state" (polis) and "nature" has been abolished [11]. Thus the natural environment has also lost its powerful function of upright, "third" correcting factor in adversity [1]. Paradoxically, the environment has become both: external, separate and yet immediate part of us that surrounds and protects us like a *second skin.* Any poisoning that we inflict on the environment as a misunderstood exterior thus becomes sepsis for us. With far-reaching consequences,—a "continue like this" does not mean the downfall of the Earth, nor the downfall of man, but it does mean considerable cuts in our living standards until the possible end of our civilization [23].

The overwhelming majority of scientists agree: The increasing anthropogenic transformation of the environment and its instrumentalization by civilization calls for new rules. It should be noted that the idea that the human, the technical intervention in the environment must not be a licentious, random one is not new: since antiquity philosophers have been concerned with the fact that our development must be subject to common rules.[1] The problems known today, therefore, exist despite many successes of the various global ethics, despite the national and international laws and agreements based on them. In 1279, Saint Francis coined the concept of sustainability, in the eighteenth century Alexander von Humboldt rediscovered it. Since the 1980s, this has given rise to a new ethic, the principles of which also contain basic guidelines for sustainable human life [11].

However, there have been no resounding successes or even changes in behaviour to date, at least on a global scale. In particular, the world economic system as a driving factor is increasingly being interpreted as actively hostile to sustainability [cf. in this volume, i.e. Weizsäcker, Wackernagl]. Instead of the "invisible hand of the market", which does everything well, the dominant economic system behaves more and more as a burden on the environment.[2] In fact, however, the reasons for failure are more complex. The International Expert Group on Earth System Preservation [9] has developed an approach to explaining and solving these problems that should be applied not only to technology, natural science, economics, and philosophy, but also to medicine, sociology and psychology.

1.3 Psychology

The "peeling out of safe spaces" quoted above produces a system of containment and demarcation. Houses with a tropical dry climate (the climate of our genetic homeland in East-Africa!), settlement structures from clans to cities, cultural landscape with useful plants but without predators, nation-states with borders and national legal systems, economic areas with trade and customs as well as different customs and traditions clearly show this. This demarcation initially acts as an extension of our body's immune system against physical illnesses. It is complemented by our mental immune system, which in turn is based on highly private or more widely accepted assumptions about the world around us. We go different ways to produce this immunization or also promotion of resilience (power of resistance) against an environment perceived as "hostile" or exploitable and its potential and actual effects:

[1] Cf. the song of Antigone of Sophocles "*So über Verhoffen begabt mit der Klugheit erfindender Kunst/geht zum Schlimmeren er bald und bald zum Guten hin./ Ehrt des Landes Gesetze er und der Götter Beschworenes Recht–Hoch steht dann seine Stadt. Stadtlos ist er, der verwegen das Schändliche tut*."; Engl.: "*So gifted with the wisdom of inventive art/he goes to the worse soon, and soon to the good / honoring the laws of the land is he and the gods conjured up right - and his city stands high then. City-less is he who boldly does the shameful.*" (cited from Jonas [11: 20]).

[2] Cf. here among others, Marx [14], Weizsäcker [27], Radermacher et al. [18], Francis [5], Küng [12].

(a) through material interventions, e.g. deforestation, city walls, extermination of predators, transformation of the wild landscape into a cultural landscape (above all for agricultural use or for recreational purposes);
(b) through immaterial organizational associations such as civic groups, but most notably the Leviathan (monster), the state, which Sloterdijk calls the third human immune system.

These achievements of civilization, which, on the basis of containment and demarcation, minimize the threats posed by the environment and maximize the benefits derived from them, have become the defining model of our cultural development. The above-mentioned material interventions have a direct effect on the environment, the immaterial on the world around us. However, the material development, which was originally vital for survival, did not come to an end with the cultural transformation of the landscape, which since the renaissance can basically be described as far-reaching (cf. the deforestation and reclamation of the landscape, which has shaped today's landscape in Europe and is today regarded as "nature"). At the beginning of the nineteenth century, it was potentiated by the, to quote H.-P. Dürr, "technical slaves of energy development from fossil raw materials", which was extended to the underground and the atmosphere, to the atom and the genome [4].

Of course, this material progress not only had material consequences. Agricultural achievements, which have released workers from food production through rising land yields and increasingly efficient labour-based commercial/industrial production have also changed society. In the course of urbanization, a densification of human habitats became necessary. According to the sociologist Peter Simmel, this led to further differences within society, to a highly efficient sectoral division of labour and to a previously unknown spatial delimitation into the city and in the countryside. This development has a high price: it creates new socially and thus also psychologically decoupled areas with their own rules, which are related to themselves in such a way that their borders seem almost insurmountable [13]. Thus, in the course of industrialization, the urban social contract of the provision of services of general interest reduced the working city dweller to himself, distanced him from nature and integrated him into a culture by providing labour as a prerequisite for securing basic human needs. This system reaches a further climax with the global financial systems, which are largely decoupled from classical material and immaterial values: meanwhile, the trading volume of shares alone exceeds the trading volume of real goods many times over.

This development is now increasingly turning out to be a problem, possibly a trap:

The fiction of security through multiple demarcation-material, but also psychological-and the associated self-reference act as a lived comfort zone that immunizes against everything disturbing; which also includes all insights that could disturb one's own world view. But this becomes a problem where sensitivity ("resonance") is required for concerns that are excluded and thus initially lie outside one's own sphere of interest, although we are dependent on them. We have become blunt, we hear the message, but it no longer resonates, it does not penetrate our heart or our mind and certainly not our actions. Resonance means, as in physics, the voluntary or “entrained” co-oscillation, a bringing oneself into harmony with external stimulation, in order to overcome the typical demarcation strategy, which each of us builds up against information, which disturbs the self-made world view.

A lack of resonance always has particularly serious consequences where joint action would be necessary. The ancient world already had to struggle with this question: “But how do the citizens of fortified cities learn to defend the walls like their own skin? How can the state become its own body for its citizens? How does the skin of the state become politically ticklish?” [22]. The state now goes far beyond the city walls of the former polis and also includes the environment in its sphere of responsibility. How can there be enough resonance for us to perceive them as our own bodies? At the moment, we live the following paradox:

– On the one hand, the division of labour has led to an alienation from production processes. Meat is on the counter, electricity comes out of the socket. This ultimately results in an exclusionary “urban” self-realization that replaces solidarity with more individualism or egoism (which in larger dimensions leads to the theory of the postnational world)
– On the other hand, there is knowledge about the existential significance of the excluded common goods and the actions necessary for their preservation; although they are demanded by the egoistic, dematerialized individual, their effect can only unfold through collective resonance.
– We as “global Homo sapiens” are thus in a figurative sense in a state which psychology calls monadic; we behave like a fetus who takes his basic necessities of life from Mother Earth via the umbilical cord and who gives everything superfluous, excrement and urine into the amniotic sac environment in the expectation that Mother Earth will take care of it. This egocentrism cannot develop any perception of the “outside”—the basis for psychoses.

But Homo sapiens also has another side: Parallel to this psychotic behaviour, there is always a reflected, critical and anything but monadically acting humanity, which has a completely different perception of the environment and the surrounding world with exposed or completely silent personalities. In this environment, ethical schools emerge within and outside the religions [2]. They create an understanding of the natural sciences and the humanities, have asked questions together with philosophers or fellow thinkers and have enriched the diversity of life plans for a successful life. The representatives of this humanistic progress can be found in all disciplines, in religion and ethics, in politics, art, science and technology. In spite of their positive influence on global development and their breakthrough towards sustainability, they have obviously not yet succeeded either. It seems as if the concrete pressure felt by many people through environmental problems is necessary for this. We are at this turning point today.

At the request: “We must change our behaviour”, the persistence forces typically lie first with those who profit personally from today’s system:

A strong political and economically organized lobby provides arguments (e.g. jobs) or exerts direct political pressure (structural such as migration, up to means of corruption) to maintain the previous system.

A powerful reason why the future risks pointed out by science are ignored is the argument: “if we don’t do it, someone else will". This ultimately leads to a situation in which collective optimal solutions are made more difficult, especially if international cooperation, e.g. on social and ecological standards, is necessary, or if economic cooperation is required, such as in the case of tax havens. In concrete terms, we are currently witnessing this in the USA’s withdrawal from the Climate Pact, or how the drying out of tax havens is being thwarted (addendum July 2021: Thankfully we are now seeing progress in both areas).

Often, however, habit and a general fear of economic losses down to the individual level seem to be the motive. This rejection is probably much deeper. It may be a reaction to the Anthropocene itself, which abolishes demarcation as the basis of our understanding of culture and now makes people solely responsible for the inner world, the environment and the world around us—no longer “fate” or the surrender to “forces of nature”. Against the background of our cultural history described so far, this represents a psychological imposition, a nightmare, a catastrophe that can only provoke a reaction: Panic; and only one strategy remains open: total suppression! Individual measures (e.g. an increase in petrol prices) can lead to socially threatening counter-movements, as the example of the yellow vests in France or the protests in Chile or Bolivia drastically demonstrate.

Sloterdijk compares this insight into the environment with a birth event, with all the disappointments and emotional overload associated with it [23]. It is based on the still dominating expectation: You, world, have put me into the world, so I can also take from you what I need! Our global economic behaviour is still based on the concept of arbitrarily available resources and infinite growth-contrary to better knowledge. It is thus at the edge of the late nineteenth century, when Karl Marx still suspected that “water and land can be used infinitely because they are infinitely available” (1867). A policy of “we first” acts as if natural laws could be arbitrarily fixed or suspended within the framework of a sovereign territory. Thoughts about possible limits do not occur in this claim attitude. The existence of an environment and a world around us is not denied. But in spite of existential dependence, there is no emotional or intellectual readiness to recognize and accept the boundaries into which the whole system is embedded. This behaviour is known as the “Tragedy of the Commons,” in which everyone exploits “freely” available resources until they are gone. Out of convenience and opportunity, facts are instead ignored, or even buildings of “alternative facts” are developed, up to and including active denial of reality. Such systems ruin themselves and others out of concrete-hard, selfish short-sightedness. Psychology speaks here of dyadic consciousness and behaviour that can develop into neurotic or even psychotic disorders. As a result, in current global politics, we experience reactions of a new limitation or demarcation, some of which seem infantile.

The realization that we are now living in the Anthropocene brings the unplannable and the threatening. It can only be solved by a new self-reflection: a society that reorders or reinvents itself in its relationship to the environment as a “third party". We are thus as a society in a state of puberty. There, in addition to childlike naivety (“innocence”), a feeling of natural security is lost and in its place responsibility and the necessity of reflection and self-knowledge arise, in the terms of psychology a development from the dyadic insularity towards a triadic opening and empathy. For us, this means nothing less than a "Second Enlightenment", which makes possible the escape of man from his self-inflicted, blind setting of limitations and demarcations.

The Anthropocene demands outrageous things from us: We must learn an attitude of respect towards the Earth system, accept its not limitless availability. We must suddenly deal with the environment as a shared world and, in addition, assume full responsibility for this shared world. We must accept the Earth system as a comprehensive shared world that simultaneously determines the future of human beings and their civilization as an absolute imperative and authority and on the other hand seems weak, fragile and can be overcome by us at any time.

The further discussion, therefore, deals only to a minimum with the possible catastrophes of the Anthropocene from Climate Change to insect dying. This is assumed to be known—albeit perhaps repressed—as the case may be. This poses the question: how can we convey this knowledge in such a way that effective measures can be taken, what should they look like, and who can implement which of them? Furthermore, we need to clarify how the imperative (which lives only on the sanctions that we absolutely want to avoid) can become a norm that receives its authority through general approval (Habermas 1981 as cited in Bedorf [1]). Because one thing is clear from the previous analysis: "It's our turn [27]" whether we like it or not. In this situation, preparation is vital.

1.4 Approaching from the Point of View of Nature and Its Janus-Headedness: Nature Threatened and Protected

Mankind is moving. The overwhelming majority of the future population will live in buildings in ever-larger cities and will make use of services of general interest that cover all their needs, from water, food and energy supply to health care and the Internet. This will exceed everything that has ever existed. These migrants will share a fundamental experience in life with those who already live in cities today: that their entire environment, buildings, roads, sewers, utilities, etc. were built by other people. This creates a sense of security, intimacy, domination and design. It is the opposite of a wild, unreliable, seemingly unconstructed nature beyond the cities, which follows unfathomable rules and offers little food, health, warmth and security and protection from rain or storm. And that's not all: many of these supposedly safe cities are increasingly threatened by flooding. Where then to move?

Current research on the consequences of the Anthropocene and the modelling of our possible futures,[3] therefore, leads to a radical reassessment of our relationship to the environment: to understand this apparently threatening natural environment as a

[3] Cf. for example the reports of the IPCC (www.ipcc.ch/reports/), the definition of the Earth system crises by IESP (www.ias.tum.de/iesp/whoisiesp/) or the research work of the Potsdam Institute for Climate Impact Research (www.pik-potsdam.de).

"second skin" of mankind. Just as our "first skin" protects us from attacks by radiation, aggressive chemicals, heat and cold, we have found and created favourable living conditions in the natural environment throughout the history of life and man. It (still) protects against radiation, supplies water and food, ensures that temperatures move within a framework appropriate for life. Above all, however, this second skin ensures the resilience of life through its biodiversity. In every past global environmental crisis, it ensured that our second skin had the answers to save life from extinction and to preserve the Earth as a place to live in.

The allegory of the second skin thus contains both: a separating, differentiating element and, at the same time, a protective, life-preserving shell that surrounds us––personal and global like our world, which is made what it is by a few meters of the living Earth or the thin breathable layer of the atmosphere.

So the original concept, the cultivation of nature, "Subdue the Earth," has to be supplemented with "take care of it as well, and treat it like your second skin".

You might say that, as in the past 5 billion years, the (environment) world is responsible for itself. Self-responsibility is a term that at first glance does not apply to "our second skin", the natural environment. Their internal processes are not the recognizable result of decisions for which someone could be called to account. The autopoiesis [26] behind these developments may seem like a "deliberate" systemic development with constant change, but it is not subject to any will recognizable to us. Or is it something like a creative will that drives these changes? But then we humans are part of this creation, aren't we?

At the latest when we use nature for our purposes, the category responsibility (of Homo sapiens) makes sense. But how can we be responsible for something if we don't recognize it and certainly don't understand it? Does the statement of incapacity for guilt apply here, e.g. in the case of young people? The situation is different from the moment we gain knowledge about the consequences of our actions. From this moment on, responsibility can no longer be denied.

Let us concretize the Anthropocene even further: Like no other large mammal, people can devise alternatives, evaluate their consequences and invent ways of implementing them. Even if this chain of action seems to differ from that observed in nature, the human goals initially do not seem to be fundamentally different from those of other living beings: freedom from hunger, physical and psychological integrity, reproduction and power. The unique combination of intellectual approaches, emotions and natural goals ultimately led to the Anthropocene, the age that began 200 to 300 years ago when humans started to rule the planet. Mankind has since immensely increased its footprint on Earth, partly because it has grown so much, partly because of the inventive approaches with which it uses the Earth system. From the first advent of agriculture more than 8,000 years ago to the use of nuclear, hydro, wind and solar energy, new technologies based on knowledge and information have been developed and used to take possession of ever larger parts of our second skin. It has been increasingly influenced. Now the Anthropocene has reached a state in which the negative consequences of our decisions can no longer be denied.

1.5 Dramatic Injuries of Our Second Skin

The Anthropocene is characterized, especially since the so-called "great acceleration" of the past 70 years, by an exponentially growing influence on all-natural processes in the Earth system. We have changed the water cycle quantitatively and qualitatively. We have succeeded in supplying the crops we cultivate, producing electricity and disposing of the waste products from our growing agricultural, industrial and social processes. Efforts to conserve resources, regulate water abstraction and treat wastewater are patchy and completely absent in large parts of the world. Rivers are polluted with chemicals, carry either too much or too little water and can only be transformed into drinking water with great purification effort. Groundwater resources are exposed to sustained pollution, and periods of drought and flooding associated with Climate Change exacerbate the problems of feeding the world's population and managing their waste products.

We have transformed almost all areas suitable for food production from their natural state as forests, wetlands, peatlands, prairies or steppes into agricultural monocultures. As the natural vegetation cover disappears, thousands of years old carbon-rich soils lose their carbon and their natural fertility. They are eventually removed by erosion or compacted by large agricultural and forestry machinery. What often remains are poor, monotonous landscapes that have been severely affected chemically and biologically by fertilizers and other agrochemicals. The resonance between us and our natural environment has fallen by the wayside. The immersion in these artificial agricultural landscapes does not convey a positive human experience, neither emotionally nor health-wise, but is nevertheless accepted by the city dwellers, because it was outsourced "to the countryside".

The greatest threat associated with people conquering every corner of the globe and transforming it according to their short-sighted logic is the associated loss of biodiversity. Every disappearing species is a lost response of the Earth system in the event of an existential (external or human) crisis.

Fossil fuels, the starting capital of the Anthropocene, accumulate in the atmosphere as heat-acting trace gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). They cause air pollution, which leads to considerable health damage, acidify the oceans and changes the global climate. Climate Change is changing the frequency and severity of natural hazards such as floods and droughts, food production and the distribution of remaining natural ecosystems around the globe. As a result, humanity is forced to devote considerable intellectual and financial resources to adapting its societies to the effects of Climate Change. We will ultimately have to leave fossil fuels, the seed capital of the great acceleration, behind to avoid the catastrophic consequences of increased greenhouse gas concentrations in the atmosphere. This is now recognized by many governments and formulated as a climate target—with a CO_2 neutrality unfortunately only reached beyond 2050.

Among most scientists, it is undisputed that a "continue like this" is associated with enormous risks for our civilization. This calls into question the "founding promise" of the Anthropocene-culture, security and better living conditions-and turns the success of Homo sapiens into the opposite. What can be the reasons for not acting here?

- The knowledge about the dangers of the Anthropocene is very mature, but is disputed by certain circles for mostly comprehensible, short-term economic reasons—either openly, as is currently the case in the USA, or concealed by inadequate measures, such as in the EU as a whole. This is made possible by the fact that (of course) there are always uncertainties about the consequences of our actions. This fundamental uncertainty, which also accompanies our everyday actions, is used above all by the doubters to justify any damage to the Earth system in the future and not to question the "how" of necessary changes but their "whether". Research is required to identify the effects of changes at an early stage and to identify and evaluate control options.
  What can we do better? This includes our personal consumption, but also sustainable services of general interest and land use free of greenhouse gas emissions, fair trade, emission-free industry and much more. Many alternatives are described, for example, in "Come on!" But here too there is still a need for research—and above all for communication.
- Beyond the acquisition of knowledge about the consequences of our actions, the biggest of all questions is and remains that of social resonance. Only a collective, broad movement generates the necessary change. Luhmann describes in detail which difficulties it makes to influence our highly specialized system based on the division of labour [13]. Changes from "inside" happen in every group beyond the optimization of the usual internal goals (profit or power or also "Sex and Drugs and Rock'n'Roll"), and only then can the group be convinced that it means its ruin if it does nothing. In the age of the Anthropocene, this can actually lead to the end of civilization. Fundamental conflicts are therefore inevitable.

The best would be a common utopia, in which we would give the future a face, set the framework conditions of a successful life for us and for future generations and enforce the necessary further developments against our own comfort and against the interests of the profiteers of the old system. This perspective may seem discouraging, but all alternatives are even worse. Particularly difficult is the fact that short-term measures have no short-term effects. If CO_2 emissions are reduced today, there is still so much of it in the atmosphere that the effect will not be felt until much later. Nevertheless, there are encouraging examples, such as the reduction in CFCs, which has actually led to a reduction in the hole in the ozone layer within a few decades.

1.6 Who Exactly Has to Take Care of the Changes?

But who is the collective "we"? Consumer micro-decisions, e.g. for driving a car or flying, each of which has only a minor impact on the environment, add up to macro-effects of worrying relevance to the Earth system. On the other hand, a single macro-decision by a car manufacturer to switch its internal energy production from coal to natural gas power plants avoids the same CO_2 emissions as almost one million cars, which populate our roads due to our daily micro-decisions.[4] Don't these considerations impose a rational prioritization of action by starting any problem solving with the big effects and the big industrial players and not especially with the individuals concerned?

Other sectors of the economy and society, such as agriculture, forestry and renewable energies, are directly dependent on the services of nature in the form of fertile soil, water, sunlight and wind. Agriculture and forestry is by far the largest human activity under the open sky. This creates responsibility for most of the global land resources and 30% of the land surface.

All the areas that humanity has used for settlements and industry to date make up a small fraction of this area. Nevertheless, it is especially the chemical industry that has completely changed the metabolism of civilization. Today, the entire periodic table of elements is used in industrial metabolism, be it in steel for buildings and cars or for spice metals for computer chips and other electrical and electronic devices, without which digitization and e-mobility would be unthinkable. Millions of organic and inorganic compounds not invented by nature are used and disposed of in the environment. This goes so far that even recreational activities, in which people consciously leave the cities to experience nature as an alternative to the over-shaped urban world, increasingly require technology, from functional clothing to countless technical mobility aids to elaborate infrastructures for open-air events (Goethe 1808).

The consequence is that without exception, all groups in society bear their share of responsibility through their individual and collective decisions. Beyond agriculture and industry, it is the energy sector, the logistics and transport sector, the media, the capital market and consumers.

Just as the defense forces are responsible for protecting citizens, the scientists are responsible for knowledge production and the teachers for education. Politics, again, is responsible for negotiating the societal consensus on the rules of social coexistence and condensing them into laws. Therefore, politics is primarily responsible for establishing the rules for the sustainable development of man and nature in the Anthropocene [11]. On the other hand, however, it is mainly politics in which long-term social necessities meet short-term sectoral advantages. We choose experts to secure our future who have convinced us that they are capable of doing so. Of course, powerful interest groups challenge politics constantly and in often opaque, but sometimes openly blackmailing ways. They circumvent possible social consensus-building in order to serve their own interests through hidden and public media actions, through direct and indirect influence. Often, the short-term advantages are the winners. But the representation of interests is not bad per se: the fight for climate-impacting measures also wants to influence politics.

However, courageous politics also runs the risk of jeopardizing their chances in elections if they follow a long-term social needs agenda that demands short-term

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[4] See, Volkswagen stellt Kraftwerke von Kohle auf Gas um https://www.braunschweiger-zeitung.de/wirtschaft/article213660469/VW-steigt-von-Kohle-auf-Gas-um.html on 8.3.2018, accessed 5.10.2019.

sacrifices. Sometimes politics also gets support for sustainability decisions from "green lobbyists" such as citizens' movements or schoolchildren who see their future endangered. Even though such movements have far fewer resources at their disposal, they are increasingly hitting the nerve of society and are therefore visible. A change in thinking is also noticeable in industry, as its decision-makers also have children––some of them have run along with "Fridays for Future" and have put pressure on people at home. There are now many real and serious efforts for sustainability on the part of the industry. This is an encouraging development.

Everyone is in demand. This must also be expressed in everyday life, and especially in our role as voters. Ultimately, it is the responsibility of an informed population to choose the appropriate politicians for the long-term tasks ahead—after Hans Jonas voting is the second fundamental responsibility after politics. We as citizens, therefore, have direct responsibility as members of civil society and as members of non-governmental organizations.

1.7 What Needs to Change? We Need to Be More Honest About Our Future and Accountable for Our Real Goals!

With the advent of civilization, human decisions began to interfere with the repertoire of self-regulating natural factors that had shaped the Earth system until then. Since then, decisions based on knowledge, information, evaluations and emotions, in contrast to natural processes, have changed the rules of the game on Earth. The vast majority of fellow creatures had to move together enormously, man has spread out. Their living conditions have changed massively, man decides who his enemy, who his friend is and decimates or promotes the respective populations. Few species, like corn, wheat, soy and rice, but also hens, cattle, pigs and goats, were able to expand their populations under the human rule in an impressive way. New variants, such as pets, have emerged. This makes a man a new, dominant factor in the evolution of life on Earth, but one that acts according to different rules.

Decisions about us and our relationship to the environment should ideally be made on the basis of knowledge and information. However, there is no direct 1:1 relationship that binds a particular decision to particular knowledge and information. On the contrary, the same knowledge and even the same information leads to different decisions in different contexts. By questioning the current path of the Anthropocene, in which humanity destroys the environment as its second skin, we are equally questioning our decisions about the environment. For they have led to the present situation. So if they clearly lead to serious and escalating present and future problems, there is obviously something wrong with our decisions! Then we have to change the way we make decisions and change the decisions themselves.

Scientific knowledge is the result of research. Knowledge about the interactions in the environment and our interventions is gained analytically. They are complex and multi-causal. However, the specialization that affects all areas of life in the

Anthropocene also leads to an accumulation of more and more knowledge about ever more specialized research objects in environmental research, which sometimes makes it difficult to see an overall picture. Therefore, scientific work also includes the ability to bring knowledge together and pour it into decisionable forms. Only a synthesis of fragmented existing knowledge creates clarity. We have entrusted the review of our current state of knowledge, e.g. on Climate Change and related sciences [10] or in the context of biodiversity (IPBES) to some of the world's most qualified personalities. This is leading to a growing consensus on action knowledge, even though it may still be incomplete in many respects. What matters now is the ability of researchers to recommend decisions when questions are still open, rather than to scientifically accompany how predictable disasters actually occur.

We do this all the time, it shows the reality of the everyday, unsustainable decisions of billions of consumers, thousands of large corporations to tens of state leaders. We all use only a fraction of the action knowledge that is available through our second skin. In the desperate attempt to reconcile our desires and necessities of life with an ever-tighter "second skin", environmental regulations often only cover smaller and unconnected fragments of reality. Good examples of this increasing and often contradictory regulatory density are our handling of waste and waste separation. In spite of "thermal recycling" and compostable packaging (which are actually but not compostable), in spite of yellow sacks, what brings all efforts into disrepute happens: the laboriously separated waste is transported by ship to Southeast Asia and unloaded there. The fact that they are increasingly resisting this makes the misery clear.

The entry into meaningful national trading with CO_2 certificates is combined with a disproportionately high increase in the commuter allowance.

Can our problem lie in the fact that we give answers too quickly and too imprudently in the form of laws and standards that have not been thought through to the end, or sometimes even "no action"? Although there are well-thought-out concepts, for example, from scientific think tanks such as the SRU or the WBGU? Aren't the fractionated concepts often the result of a lack of answers to the right questions?

What would be such overarching, fundamental questions about the relationship between nature and humanity in the Anthropocene? First, we see two such questions, the first of which is:

> In what world do we want to live and what kind of nature do we want?

This is *the* normative question of the Anthropocene. It expresses human dominance over nature and the delimitation and demarcation of the environment, but first and foremost human responsibility for the environment. Any attempt to reshape the interface between man and nature and any attempt to overcome the limitations of the environment should be based on a consensual answer to this fundamental question. Consensus, however, arises on the basis beyond the existing knowledge of action and includes faith, fears and emotions.

Natural laws and insights into the sustainability of nature are the basic prerequisites for a sustainable Anthropocene. No one can avoid them. The scientific basis of facts about nature and its laws is the stage for consensus about the world and nature in and with which we want to live.

The second question is this:

Which behaviour leads to the desired world?

It is at least fundamentally verifiable. Let us first assume that humanity, through a magical insight, reaches a consensus about the world in which it ultimately wants to live, and about the kind of nature around it. Our second question then implies that our intellectual abilities make it possible to show coordinated behaviour and to develop the necessary technologies to realize the world and the nature we want to create. Thus, at every step on the way to this desired world of consensus, we could answer the question of whether we are moving towards or away from consensus with this step. This management approach is attractive because it makes it possible, at least theoretically, to begin the journey to the desired world at any stage of social development and to trust in the power of self-organization [30]. However, this bold assumption about the abilities of management is not trivial.

Therefore, it may be helpful at this point to first try to get to the bottom of the implicit assumptions of the second question. It is obvious that our current behaviour has the effect of creating an environment that is distinct from the natural world without human beings. This difference is by no means a coincidental by-product of unintentional human behaviour, but rather the supposed meaning of our actions themselves. It is driven by man's desire to create an environment for his species that prevents hunger, thirst, disease and threats and ensures human integrity. However, for these man-made living conditions and their environment to be sustainable, they must at least be based on the basic laws of the natural world. These can be challenged, but ultimately not negotiated.

This immediately raises another question: What if it turns out that our extremely laborious global process of balancing social and cultural forces for a consensus on the world in which we want to live should violate the laws of nature? The price of mistaken decisions due to a violation of natural laws could be environmental disasters and a disrupted life-support system. Humanity would certainly not peacefully accept this forced correction. Our civilization is at stake here.

A breath of hope for an overarching, global consensus on a desirable future for a sustainable world and nature was the Paris Agreement of 2015 with a consensus on cornerstones and guard rails to combat Climate Change. However, it hardly led to concrete global measures to protect the environment. Instead, fragmented, partial regulations and action programs are emerging that aim to minimize the violation of sustainability.

The United Nations also adopted the Sustainable Development Goals (SDGs) in 2015. At regional to local level, from the EU to the federal states, complex, sometimes highly specialized and far-reaching guidelines and laws were developed and enacted for the management and protection of water bodies, insects, forests, agricultural, alpine and wetland areas, for combating the spread of impervious areas and for reducing the consumption of fossil fuels. They all try to bring environmental decisions more into line with the laws of nature and to overcome the limitation and demarcation of the environment. Each regulation is the result of protracted and painful battles between the rules and possibilities of nature and the aims of social interest groups, for example on the part of agriculture, industry, consumers or tourism. They all claim to already know the world in which and the nature with which they want to live and fight for the implementation of their interests. The end of these controversies is often marked by regulations that violate the long-term sustainability of nature in order to pacify short-term social conflicts. Or which have become so complicated by supposedly fair exceptions and detailed regulations that they hardly seem enforceable. Or which, through the participation of lobbying associations, already contain the loopholes from the outset which later render them ineffective? These wildly fragmented regulatory efforts are confronted with a phenomenon that is strikingly similar to what we have seen in terms of our knowledge and understanding of people and the environment. Just as the overwhelming amount of actionable knowledge and understanding we have is useless as long as it is not used, there is a huge global web of environmental policies and regulations that do not work due to lack of stringency or acceptance. Even in Europe, these effects regularly occur on a remarkable scale. Just consider the diverse EU treaty infringement proceedings (most recently on air pollution control or nitrate fertilization). Worse still, in many sectors, there are even absolutely counterproductive incentive systems in the form of subsidies or tax loopholes, as is the case in agriculture or finance.

What would happen now if all guidelines, laws and regulations were harmonized and implemented in the sense of sustainability? Is it true that simultaneous compliance with all environmental regulations at all levels would almost automatically lead to a “sustainable Anthropocene”, even if they do not follow a common overarching concept? Every regulation and every incentive system, no matter from which part of the Globe or for which specific purpose, would have to be cooperative and they would all have to work together in a consistent way without slowing each other down, but ideally even strengthen each other in their positive impact on the environment. It is also assumed that the inevitable conflicts of objectives between ethically highly legitimate objectives have been resolved (e.g. negative environmental impact of the cultivation of renewable raw materials: pesticides, nutrients, erosion, water demand).

We do not know!

In view of these considerations, it is rather unlikely that our current behaviour, which is based on the partially informed decisions described above and the partial observance of the existing canon of regulations, would seamlessly lead to the world and nature we want. It is, therefore, high time to put the existing regulations to the test in this light and to thoroughly examine them. The very practical question is whether they are suitable as rules of the game for a “sustainable Anthropocene". At the same time, the answer under the heading “What is it that we have to change?” also requires information on how they can generate the necessary resonance among all those involved so that they are accepted and complied with.

After 200 to 300 years of Anthropocene and 70 years of great acceleration, we are inevitably at the beginning of a new epoch of the Anthropocene—let us call it Anthropocene 2.0. Its basic principle must be sustainability. A digital, virtual version of reality will become its constant companion. This digital world promises the ability to simulate everything in a model way and to find out in this way how the respective interventions will affect it.

While models tend to be deterministic and do not know the concept of surprises, which is an enormous source of error in complex systems, they can still provide a first approximation of estimates. Together with constant tracking and calibration based on past experience, they offer a valuable opportunity.

They help to identify where regulations cover conflicting objectives, e.g. between agriculture and water, or between energy production and biodiversity. Can we ensure, through proper design, that the effectiveness of the whole regulatory orchestra is greater than the sum of its parts? What, for example, are rules that reinforce each other in their overall effect? All this could be investigated and evaluated through systematic simulation in the digital virtual world before it is unleashed on humanity and nature. Starting points from which we can begin the virtual analysis of desirable futures already exist: termination of fossil fuel consumption, zero-emission industrial production, maximum possible efficiency in the use of nature's services, ecological intensification of agricultural production on ever smaller parts of the planet's land surface, renewable energy sources affordable to all, respect for nature and every living being and expansion of biodiversity reserves.

2 Epilogue: Which Concrete Steps Create Resonance and Thus Lead to Changes and Sustainability?

There is no lack of knowledge about how humans deal with their second skin, about its causes, processes and effects in the Anthropocene and about ways of overcoming them. Existing knowledge forces us to conclude that ignorance is no longer an excuse to postpone the search for a sustainable Anthropocene until tomorrow. In contrast to existing action knowledge, the question of where the journey must and should go, how it should be implemented, and how social consensus can develop for this is still far from clear. To shape it is the task of the twenty-first century.

All we can do at this point is to point out places where, from our point of view, the search is worthwhile and where the journey could begin. We do not rely on fear—even if it would be understandable—but on optimism, on a positive change and chances, on the fact that we can take the future into our hands. Five ideas.

2.1 Technical Solutions

The aim of technical solutions must be to radically reduce the exploitation of nature and thus radically reduce our footprint on Earth. Approaches to this exist and must be consistently pursued. They concern, for example, zero discharge in production (at least for critical substances such as fluorine chemistry), increased efficiency (LED, transport, shipping), agricultural policy, e.g. organic farming or sustainable intensification of agriculture and affordable renewable energy sources. As the population continues to grow, all the technical registers must be pulled out for a sustainable Anthropocene. They must be used to give the environment the space (in the literal sense) it needs to be healthy. Scientists, designers, engineers and artists are in demand [3].

A large number of authors deal with the technical, economic and cultural upheavals of our time, which are often characterized by the word digitization [7, 15, 17, 19, 24]. Bringing salvation alternates with scepticism when topics such as artificial intelligence, genetics and eternal life, autonomous machines, total communication and the merging of humans and machines are mixed into a confusing picture of the future. What is frightening about all the attunement to the future, however, is that our relationship to our second skin and the necessary overcoming of our and its limitation and demarcation hardly occurs there.

2.2 Virtual Worlds

When reading this literature, any individual of Homo sapiens might view itself slipped in a virtual, world where it can seek and shape its identity, and which has moved further away from its environment than it exists today—and which it cannot disturb any further. If we assume that everything takes place in the mind and on the computer, if the virtual world replaces reality, the environment is consequently out of the game. One does not even break the laws of nature, one apparently simply leaves them behind by pretending to the mind that it can take on any perspective, that gravity has thus been overcome once and for all and that the laws of nature are no longer needed. You can simply turn them off. The fact that such developments can be considered is due to the rapid development of virtualization and communication. It goes, and this is already evident in the field of computer games, towards a complete service of our sensory organs (eye, ear, smell, skin and sense of touch) with digitally generated signals of a virtual world.

For the further development of our communication with the environment through our sensory organs, it is, therefore, a rather small step from reporting on bears on a screen plundering the rich salmon grounds in Canada (a highly natural process) to an immersive representation of the same story in a virtual world that we can take for absolutely real because it takes place directly in our sensory organs. The goal is to make the created nature a more real and exciting one. In fact, we are less and less willing to get involved in its real slowness, the mosquitoes, the sweat and the dangers of real nature. Even today a large part of the population prefers a virtual experience of nature in front of the television screen to a true, unpredictable experience of real nature.

But this should not deceive us. Our second skin is obviously able to create resonances in us to a high degree; even unfortunately, in the meantime, they are mainly second-hand. Just think of the polar bear drifting lonely on a small floe in the Atlantic, a picture that has attracted a lot of attention to Climate Change, even though it has not been proven to have much to do with it. Or the breathtaking series by David Attenborough on BBC, which both show the beauty of nature and save you hours waiting in the swamp for the right scene. The iconic "Blue Marble", the blue Earth photographed from Apollo 17, has shown us visually that we are all sitting in the same spaceship Earth. All this shows that our emotions still have a relationship to our second skin, which, placed in the right context, can influence us much more strongly and sustainably than the overwhelming evidence of all action knowledge.

At the end of the day, however, this new digital world will also be powered by electricity, hopefully from renewable energy sources. A power failure would lead to a hard landing in material reality, as the failure of a power plant shows. It is equally hard when the sky becomes dusty due to a volcanic eruption and thousands of flights have to be cancelled. Even if we were to eat synthetically, regenerate the air and get all our sensory impressions from the virtual world, we would still be connected to the environment; we would still be inhabitants of this planet and would still be dependent on the light of our sun.

2.3 Realistic Resonances Generate Real Utopias? (Utopia Development of an Eco-Social Market Economy)

So the key question is: does such a worldview of future immortality create resonance in us in the form of immaterial spirit, the virtualization of reality, the fusion of man and machines created by him? Is this worldview of an ultimate Anthropocene the answer to the questions "In what world do we want to live?" and "What nature do we want to have"?

There is an urgent need to deal with the role of the environment in the age of digitalization, as the German Advisory Council on Global Change has exemplarily begun in this year's report "Our Common Digital Future".[5]

The economy plays an important role in the search for resonance. The social market economy, at least in the West a constant companion of the Anthropocene, has so far proven to be extremely successful in terms of resonance. After all, the focus of current human existence is on work for life support and consumption. Securing one's existence, leisure and consumption were and are highly effective in compensating for the frustration of alienated work that sometimes arises.

In view of the global environmental development and in the light of the forthcoming far-reaching change in the world of work in the course of digitization, however, the conclusion is that a further development of the social market economy is urgently required. This is primarily because the tendencies towards economic foreclosure and utilitarianism are intensifying. The promise of the market economy that growth and industrialization will benefit all those involved is being unleashed in the hands of the very few in view of the accumulation of unprecedented wealth.

[5] https://www.wbgu.de/en/tags/digitalization, accessed 19.12.2019.

The costs of this out-of-balance economy have, however, always and increasingly been distributed to future generations: ecological degradation, desertification of the landscape, emission of climate-active gases such as CO_2, extinction of species. The balancing medium, consisting of taxes and levies, is increasingly concentrating on the middle class. The large assets and, above all, the corporations of the digital economy are, legally partially legal, morally perverted from their duty to cooperate. Worse still, the utopia of the market economy, that a person's identity and meaning is based on his work, dissolves when he is replaced by "intelligent" machines. This will lead a large part of the population into unemployment and, worse still, into insignificance. What remains, man as a meaningless "consumer machine" in a destroyed environment, is not suited to make people's souls vibrate and create resonance.

There is, therefore, an urgent need to adopt the existing approaches to further developing the market economy into an eco-social market economy and to put an end to its political struggle and blockade. Such concepts already exist [8, 18]. As a member of a community, human beings must be able to recognize a new meaning of their existence in a future sustainable Anthropocene, especially when the imperative of sustainability will change the three previous resonance factors of existence, leisure and consumption [29].

2.4 *Role Models on the Way to Happiness in Life?*

The starting point for this further development could be an image of a diverse future society in which the individual's search for happiness and contentment is given high priority, in which freedom means the freedom to do not "everything" but "the right thing". Just as biodiversity enriches nature and increases its resilience, so the diversity of the most diverse lifestyles lived at the same time enriches a society and strengthens its resistance to external influences. Why shouldn't behavioural utopias such as asceticism, renunciation, sustainable consumption based on regenerative energy sources and recycling, the search for immaterial happiness, vegan nutrition and much more exist and develop simultaneously in a society?

So how do we set out on the path to a sustainable Anthropocene? Shall we begin the path with a broad discussion of society as a whole, involving all sections of the population and clarifying the questions "In what world do we want to live and what nature do we want to have" and "Which behaviour leads to the desired world?".

We mean "no". This is not to suggest that not all should be taken and somebody should eventually be left behind, on the contrary. Everyone should be able to participate. We just have no more time to lose. So why shouldn't those who have chosen themselves to make themselves smart and to take part in the search, to expose themselves to the changes that a journey brings with it and who are curious about what we will probably get for what we renounce, go for it? Why shouldn't scientists, ethicists and church representatives, influencers and politicians and all others who want to contribute, be able to bring their energy into the project if they are willing to keep one promise: to welcome everyone on the way who is still undecided today and decides to go along tomorrow. Waiting for the last sceptic means gambling away the future, especially when there is sufficient knowledge available.

It is, therefore, a matter of jointly focusing the spotlight on the future, developing utopias of a good life in the sustainable Anthropocene, simulating future scenarios, telling narratives and reaching agreements. No knowledge of power should emerge, no economic enterprise should be commissioned with it or worse, should commission itself, all data and methods must be free and open, science should contribute its reputation and its abilities as a reliable partner and the state should regain its role as a reliable, just and ordering power.

2.5 Optimism and Pleasure as a New Model for the Alternative Generation Anthropocene 2.0?

We are not without hope. With Fridays for Future the youth, the future, has spoken. They say: “do something!”.

The “do something” does not have to provoke a personal bad conscience! Each one of us personally cannot switch off a coal-fired power plant or convert it to gas, no one can make e-cars affordable on his own (or a fossil-fuel-driven one unaffordable), no one can simply issue a regulation to install a methane capture system in a cowshed, no social balance can be individually created with his neighbour or with the disadvantaged in society. Also, the activists of Fridays for Future cannot do that. It would be almost unforgivable, however, if they would have to miss the experience of the strange as enrichment in our growing together world due to personal feelings of fly-shame in the end. There is no sense, in our personal search for utopias and in our contemplation on what we may sacrifice, to forget to address the really big levers and how we can use them radically for a sustainable Anthropocene. The call “Do something” calls for the solidarity of the old with the young in pushing through the great levers of change against the neoliberal attempts to privatize responsibility.

It is time to expose this eternal “everyone is responsible for saving his own world (food, emissions, travel and everything else) and if everyone does this selfishly and voluntarily, everything will end up good” for what it is: the neoliberal excuse for deregulation and redistribution to the realms of this world [6]. It can and must be done differently: to require decision-makers in business, associations and politics to do the right thing, to affirm that in elections and at the same time to have the necessary dose of optimism and pleasure in establishing rules for a world worth living in and to make them their own. And, as said, with optimism and pleasure!

The utopia of today’s world originated at the campfires of the Holocene. There a world without hunger, danger and illness was dreamed. The way into the present was certainly blurred at that time. Nevertheless, we set out on our way. Even today we search for it and experience on our journey how the utopias of the Holocene are transformed into the dystopias of the present. Where will the mental places be, where new resonance will emerge and where the indicated, necessary changes will come into harmony with the dreams, desires and goals of people today? Is it the digital campfires of the Internet? They have the potential to set the whole of humanity vibrating for the yet undiscovered utopia of the "sustainable Anthropocene". Perhaps it is the outcome of a "Second Enlightenment", the exit of man from his self-inflicted limitation and demarcation. It would end our tyranny over the environment and thus dissolve our self-imposed isolation.

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Natural Ecosystems and Earth's Habitability: Attempting a Cross-Disciplinary Synthesis

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Abstract There are two contrasting views on life and Earth's habitability. One view is that the program of environmental regulation by life cannot exist, because it is genetically unstable. A program of "common environmental good" cannot be stabilized by natural selection and would have been disrupted by selfish mutants. The ever-changing Earth's environment has remained suitable for the ever-adapting life by chance. The second view is that the Earth could not have remained habitable by chance, because the life-compatible environment is physically unstable. Life regulates the environment, but the program of regulation has persisted by chance (for some reason, the disruptive mutants never spread). Neither view forms a quantitative theory of life-environment interaction. Here I discuss the biotic regulation theory, whereby the genetic and environmental stability are mutually guaranteed: the genetic program of environmental regulation by life encodes such an environment where disruptive mutants cannot spread. The key interdisciplinary question is what these environmental properties are. This is not an academic question: once the natural ecosystems are destroyed, the environment will rapidly degrade even if carbon emissions discontinue. Global change mitigation efforts can be misguided if the key role of natural ecosystems in stabilizing a life-favorable environment continues to be neglected.

Keywords Biotic regulation · Climate stability · Biotic sensitivity · Genetic program · Habitability

1 Introduction

Our civilization is in a global ecological and environmental crisis. Besides accumulation of atmospheric carbon dioxide, a major destabilizing process in the industrial era has been the destruction of wildness, especially the elimination of forests. During the past two centuries, primary vegetation has been exterminated over 40% of the land

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area [19]. Today, the degradation of the natural forests by humans continues unabated. Repeated calls from groups of concerned citizens, including some scientists, do not change the trajectory of our civilization destroying natural ecosystems.

It might appear that this critical situation is due to an insufficient understanding—by the society as a whole and decision-makers in particular—of the scientific arguments for ecosystem protection. The science is settled but the public is lagging behind scientists in the appreciation of an urgent necessity to preserve the still extant natural ecosystems. In that case, scientists could do little more than popularizing their messages more actively [38].

In reality, as I will argue here, the mental inertia of our thinking species appears minimal. The current globally destructive attitude toward natural forests accurately reflects the prevailing scientific paradigms. These paradigms had formed before the humanity began to experience large-scale environmental problems. They do not correctly capture the life–environment interactions and require a comprehensive reappraisal.

Specifically, the *limiting principle* in ecology (Liebig's law) and the *survival of the fittest* paradigm in evolutionary biology (which also underlies the ideology of modern market economy) both formed using evidence from artificial, human-impacted biological systems (agriculture), and processes (artificial selection). At large, these concepts view living objects as existing at the mercy of an external environment, which shapes their functioning and creates a perpetual need to adapt or perish.

However, artificial biological systems and processes differ from natural biological systems and processes in one commonly neglected but crucial aspect: the artificial ones lack sustainability and persistence. Indeed, while natural ecosystems can thrive for millions of years without perturbing their environment, all human-supported biological systems, including the civilization itself, are inherently unstable; they exist as long as there are nonrenewable environmental resources to deplete. Likewise, while natural biological species persist on average for several million years [31], the domestic sorts of plants and animals are unstable. As the human population itself, they are subject to rapid genetic degradation [29, 36].

Historically, people responsible for the development of modern science used to live in artificial biological systems, and continue to do so. Extrapolating knowledge obtained from these unstable systems to the rest of the biosphere resulted in the neglect of the stabilizing impact of natural ecosystems. When environmental science became global, the first indications of the stabilizing influence of life became available for discussion (e.g., [27, 28]). This new evidence was forcefully fitted into the old paradigms. It was misinterpreted as occasional life-mediated negative environmental feedbacks rather than the key genetically encoded principle of life organization [14]. If the stability of the Earth's environment favorable for life is maintained by natural ecosystems, then, even in the absence of direct environmental disturbances like, e.g., carbon emissions, degradation of these regulatory mechanisms presents a major threat to the humanity, and the more so, the longer our species remains unaware of this fact. For the biosphere to preserve a global stabilizing function, the self-sustainable natural ecosystems must be globally protected from exploitation. The biota should be preserved not in biodiversity hotspots, advanced agricultural systems, or zoos, but on large territories, such that the stabilizing power of these natural ecosystems would compensate for the violation of natural processes that humans perform elsewhere.

2 Life as the Realization of a Genetic Program

Life is a process that transmits genetic information, which is quantum ("digital"), from one generation of classical ("analogous") objects—living organisms—to another [14, 47]. This information governs all life processes: out of all possible biochemical and biophysical reactions that could occur in the biosphere, only certain non-random processes actually take place at nonrandom rates. Under similar environmental conditions, different genetic programs may govern drastically different behaviors and impacts. For example, while most birds build nests and feed their progeny, the cuckoo does not possess such a genetic program and has to rely on others bringing up its young.

Another conspicuous property of genetically programmed processes is that they, to various degrees, decouple the organism from the limitations of its external abiotic environment. Consider the opening and closure of plant stomata—the microscopic pores that regulate CO_2 uptake and H_2O release by the leaf. The so-called passive component of the stomata closing/opening is governed by ambient relative humidity in a relatively straightforward way: the two guard cells surrounding each pore lose (regain) turgor at high (low) vapor pressure deficit. Depending on the mutual configuration of the guard cells, these turgor changes can mechanically induce either opening (as in *Sphagnum* spore capsules) or closure (as in other plants) of the stomata in dry conditions [4]. A similar passive mechanism determines the shape of dry versus wet conifer cones, modern sustainable architecture uses it in biomimetic hygromorphic materials [18].

However, there is also an active complex hormone-mediated control. It allows plants to sense environmental conditions and regulate the stomata aperture depending on diverse combinations of internal and external stimuli like light, carbon dioxide, and temperature [1, 4]. For example, if the external conditions for photosynthetic CO_2 uptake are unfavorable (low light), the plants can keep stomata closed even at a low vapor pressure deficit. Accordingly, ambient humidity no longer dictates plant functioning.

Parameters of the genetically programmed processes are properties of the biota itself that cannot be deduced from environmental conditions. Compare a poikilothermic animal that lacks a genetic program for body temperature regulation with a homeothermic animal that does possess such a program. The poikilotherm's body temperature can be estimated from environmental parameters (radiation flux) using fundamental physical relationships (Stefan–Boltzmann law) and some simple physical properties of the organism (albedo of the body surface).

The homeotherm's body temperature cannot be specified in this manner but is prescribed instead by complex genetically encoded biochemical processes within the organism. Similarly, the persistence of organic molecules in the soil cannot be deduced from their molecular properties but is controlled by complex biological and ecological processes in the ecological community [40]. Consider a mite parasitizing on a deer. Despite the flux of solar energy changes radically, from day to night and from summer to winter, the mite barely notices it. The deer maintains a stable body temperature around 37 °C. This stability is of complex nature. Plants absorb sunlight to generate biomass. The deer knows how to find this biomass and eats it up. The food burns within the body in such a manner that the resulting heating precisely offsets heat losses to the environment, irrespective of whether the latter is cold or hot, while the body temperature remains constant. On top of all, this complexity sits the mite and enjoys thermal stability.

What determines the steady-state value of temperature experienced by the parasite? While we cannot deduce its value from the environmental parameters, it is not arbitrary. The information about which body temperature to maintain is contained in the genome of the deer. If one replaces this genetic program with a different one, by transmitting the mite to a different host, the temperature can change too. For example, in passerine birds it will rise to almost 40 °C.

In the presence of a genetic program of environmental regulation by life, humans within the biosphere can be compared to parasites within an animal body. Similar to the mite, humans remain largely unaware of the pillars of our existence and thus misguided about how to cope with unfavorable environmental changes. There is more to it: if the parasites take an excessive share of the animal's resources, the animal dies together with the parasites. If the parasite is a thinking animal capable of rational behavior, it is in our interest not to undermine the system that is regulating our environment and preserve a significant part of the biosphere untouched.

Deciphering what subprograms the big genetic program of life carries allows one to make use of them. One example is the programmed death. The death of an organism can happen "by itself" since all classical objects age. Alternatively, death can be genetically programmed in that sense that it will occur non-randomly at a certain life stage well before the body actually wears out (e.g., Pacific salmon dies shortly after reproduction). If a species had such a program, switching it off would produce a radical increase in longevity. The question of whether death is or can be programmed has been a matter of active and sometimes controversial discussions [23, 24, 26, 45]. Some of this debate, as discussed below, is relevant to conceptualizing the life-environment interactions.

3 "Survival of the Fittest"

All contemporary living beings have a single common ancestor, from which we have inherited its genetic program modified by the four billion years of biological evolution. What is the minimal amount of information that had differentiated life from the inanimate world? For example, the first organism must have possessed the information about how to synthesize a copy of itself. Such information could not evolve, because the evolution itself is contingent on the ability of living beings to reproduce. Did the minimal genetic information kit include the program of environmental regulation, which then persisted through time maintained by natural selection? Is this proposition necessary to explain life persistence?

Neo-Darwinism answers "no." Two observed properties of the living beings appear sufficient to understand the phenomenon of life: besides reproduction, living things must be able to mutate such that at least some of the offspring differ genetically from their parents. This naturally happens, because the probability of exact copying of the DNA molecules (the molecular carriers of genetic information) during cell divisions is less than unity. During reproduction, some letters (nucleotide pairs) of the genetic code are copied with errors (mutations).

Neo-Darwinism postulates that if the environment changes, those individuals whose genetic program is better suited to the new conditions will produce more offspring and start dominating the population. Individuals less fitted to the new environment will not leave enough progeny and may ultimately die out. This is the Neo-Darwinist view of natural selection: environmental changes drive genetic changes and, hence, biological evolution.

This "survival of the fittest" principle may seem tautological, since nothing generally defines "the fittest" except its exceptional survival. In fact, however, this formulation reflects a fundamental, if implicit, premise of evolutionary biology: whatever changes life's environment undergoes, there are always some individuals to survive.

Based on this axiom, modern evolutionary biology cannot be qualified as a quantitative theory of life–environment interaction. It leaves the key theoretical questions unanswered, namely how genetic diversity and environmental change are linked. If some environmental parameter (temperature, pH, CO_2 concentration) changes by a certain amount, how much and what kind of genetic diversity must a given species possess to survive in the new environment with at least the same productivity? In other words, what is the probability that among the genetically different individuals composing a species there is at least one individual capable of producing the same or larger number of viable progeny in the new environment as the dominant individuals used to produce in the old one?

If evolution is driven by natural selection in an ever-changing environment that favors the best-fitted genetic variants, the evolutionary tempo and mode should reflect the rate R at which these variants are generated within a species. The larger the value R, the higher the probability of there being an individual fitted to any possible environmental change (e.g., [24]). On the other hand, given the prevalence of the long periods of evolutionary stasis, when species remain morphologically unchanged for the most time of their existence ("punctuated equilibrium"), the tempo of genetic and morphological changes associated with environmental adaptation should be related to speciation rates.

Rate R is proportional to the total number of individuals in a species and inversely proportional to their generation time. Differences in R values between the small, numerous, rapidly growing organisms and the larger, more slowly growing organisms constitute 10–15 orders of magnitude (i.e., 10^{10}–10^{15} times). Meanwhile, the mean species duration (i.e., the time since origin to giving rise to another species) differs by two orders of magnitude at most and shows no correlation with *R*. For example, some of the longest living species (25 million years) are found among lizards and some marine unicells [31].

On the other hand, data from domestic animals unambiguously testify that any features not continuously supported by selection undergo rapid genetic degradation [36]. For this reason, despite possessing high genetic diversity (see Fig. 10.9 in [11]), domesticated species cannot survive when reintroduced to the wild environment. This does not support the statement that a population generally carries individuals capable to survive in any environment.

As long as the question of how genetic diversity and environmental adaptation are quantitatively linked remains open (in evolutionary biology it is not yet posed), the proposition that life has been able by chance to genetically adapt to all environmental changes that might have happened during the last nearly four billion years of life existence, is unjustified.

4 Gaia and Daisyworld

Furthermore, the view of life as a chance-driven genetic adaptation to an ever-changing unpredictable environment comes in conflict with the evidence suggesting that a lifeless Earth should have become unfit for any life long ago because of the destabilizing external abiotic processes. Prominent examples are the increase of solar luminosity and the infiltration of CO_2 from the Earth's core. On a time scale of hundreds of millions of years, either process could have raised the planetary temperature to a life-prohibitive value. Since this did not actually happen, it must mean that life has been imposing some stabilizing impacts on the global environment rather than merely adapting to random environmental changes. Some of such negative feedbacks have been identified: e.g., the biota removed the excessive inorganic carbon from the atmosphere and stored in the form of carbonates and inactive organic carbon in sediments.

Furthermore, the modern environment appears optimized for life—something that cannot be explained by chance. For example, the observed ratio of concentrations of life-important inorganic elements like nitrogen and phosphorus in the ocean is precisely such as they are used by life (the Redfield ratio). This suggests that the physicochemical environment of the ocean was formed and is maintained by life itself.

Considering this and related evidence James Lovelock formulated the Gaia hypothesis (see references for the discussion below in [46] and [7]). It posits that life is shaping and regulating the environment on Earth maintaining it far from the physicochemical equilibrium that would set in on a lifeless planet. In its original formulation—Earth as a super-organism, which regulates its own "internal" milieu—the Gaia hypothesis was intensely criticized by Neo-Darwinists. They argued that environmental regulation on a global scale cannot be maintained by natural selection. Environmental regulation implies that organisms must act in concert for "the common good" which they somehow "foresee," while natural selection favors individuals that act on their own (maximize their reproductive success) without any teleological foresight.

In an attempt to refute these criticisms, Lovelock presented his Daisyworld model. The white and black daisies, each maximizing their growth rates in the optimal environment, without "acting in concert for the common good" nevertheless produced a partial stabilization of global temperature in the face of an external disturbance represented by a changing solar luminosity. When the mean global temperature rises above the optimum because of increasing solar luminosity, the white daisies who, because of their higher albedo, enjoy a slightly lower *local* temperature than the global mean, find themselves closer to the universal growth optimum temperature than the black daisies (who, because of low albedo, are *locally* warmer). As the white daisies spread more widely, the planetary albedo increases, and the global temperature declines thus counteracting the initial external perturbation.

The Daisyworld model received considerable attention in the literature, but it did not stand as the intended proof of environmental regulation by life. It was pointed out that there is no mechanism by which the information about environmental regulation, even if it was initially present, could be preserved through evolution by natural selection. For example, the environmental regulation in a Daisyworld is disrupted by the appearance of a mutant gray daisy (a "cheat") that does not synthesize either of the necessary pigments (black or white) but invests extra resources in reproduction, thus growing faster than either black or white daisies. Such a mutant can spread over the planet forcing out the white and black daisies after which the planetary regulation ceases and life ultimately perishes. "Good guys come last", i.e., natural selection does not maintain behaviors contributing to the "common good" [5].

This type of arguments proved to be near fatal for the Gaia hypothesis. The only thing that the mainstream science took from Gaia was the explicit recognition that life does impose a certain non-negligible impact on the environment (with several documented examples of a stabilizing impact like carbon deposition in sediments). On the other hand, life is thought to adapt to the biotically mediated environmental changes in very much the same manner as it adapts to random abiotic changes. This *co-evolution* of life and its environment allegedly explains why the life-mediated environment seems to be optimized for life (because life has adapted to it).

In other words, one can say that Gaia, in its original formulation, succumbed to Neo-Darwinism, while the idea of environmental regulation by life for life succumbed to the idea that life on Earth has persisted by chance. Indeed, one could argue that, inasmuch as Neo-Darwinists presume that environment has remained suitable for life by lucky chance, the defenders of Gaia should be allowed to presume that, by another lucky chance, some stabilizing biological processes that did occur in the biosphere were allowed to operate for considerable periods of time and were not disrupted by either biological mutants or any abiotic processes (Table 1). Similarly, for yet another chance, the biotic impact has not driven Earth's environment to uninhabitability—i.e., among the biotic impacts the stabilizing ones dominated. Such an admission would, however, mean that both concepts agree that the persistence of life on Earth could not be ensured by the inherent properties (information) encoded in life itself.

Table 1 Different approaches to the problem of environmental and genetic stability

Concept/issue	Environmental stability	Genetic stability
Neo-Darwinism	Earth's environment may have remained suitable for life by chance. Life adapts to environmental change	The program of environmental regulation by life cannot exist, because it would have been genetically unstable. Such a program of "common good" could not have been stabilized by natural selection and would have been disrupted by mutants
Gaia/Daisyworld	Earth's environment could not have remained suitable for life by chance, because it is physically unstable	The genetic program of environmental regulation by life may have persisted by chance. Disruptive mutants have never appeared or spread
Biotic regulation	Genetic and environmental stability are mutually guaranteed: the genetic program of environmental regulation by life encodes such environmental properties that make the spread of a disruptive mutant impossible. What are these properties?	

At this point, we note once again that neither Gaia nor Neo-Darwinism represents quantitative theories of life–environment interaction. Neo-Darwinism (and generally theoretical evolutionary biology and genetics) is concerned about how to explain the observed patterns of molecular evolution and speciation but is largely agnostic with respect to the environment, including the problem of its stability. Gaia, on the other hand, considers the geophysical and biophysical processes in the environment but has no quantitative clues to the genetic and evolutionary peculiarities of life and their dynamics. Accordingly, models aimed to bring the two concepts together operate with arbitrarily chosen timescales of genetic and environmental change. For example, the so-called "guild" model illustrating the evolution of a closed matter cycle with different trophic groups (guilds) of organisms, allows the matter cycles to remain open for an arbitrary time—until there appears a mutant able to (partially) close them [8]. That the environment can meanwhile degrade for a state unfit for life is not considered.

5 Biotic Regulation

The concept of biotic regulation of the environment aims to reveal and quantitatively describe how the inherent properties of life ensured its persistence on Earth [11, 14]. In such a setting, we must first describe what kind of information life must contain to secure its existence through time. Second, it is necessary to explain how this information can be maintained by natural selection (i.e., why no disruptive mutants could ever conquer the biosphere).

Let us discuss the first question and see how the regulation of the environment by life demands a nonrandom correlation in the functioning of different organisms. Life is based on the continual recycling of chemical elements like carbon, nitrogen, phosphorus, etc. Of these, carbon is the most abundant. Some organisms (plants) can synthesize organic matter from inorganic compounds like CO_2 and all living organisms are able to decompose organic carbon back into inorganic constituents. Other conditions being favorable (sufficient sunlight, water, other nutrients), functioning of the biota ultimately depends on the availability of CO_2. Atmospheric CO_2 also happens to be a second important greenhouse gas. It is well suited for a brief illustration of the biotic regulation principles.

In the steady state in a closed system, synthesis $P^+ > 0$ (which produces organic carbon and reduces the amount of inorganic carbon) and decomposition $P^- > 0$ (which does the opposite) must coincide (Fig. 1a). If M^- occasionally increases from $M_0{}^-$ to $M_0{}^- + \Delta M$, $\Delta M > 0$, to bring it back to the original value the difference $P^+ - P^-$ must be positive. This can be achieved in several ways: either the decomposers reduce P^- relative to $P_0{}^-$, or the synthesizers elevate P^+ relative to $P_0{}^+$, or both.

While in heterotrophs the energy and matter stores partially coincide in food (oxygen comes from the atmosphere), in autotrophs the energy and matter stores are decoupled (Fig. 1a). Energy for autotrophs comes with solar photons that have zero mass and thus, unlike organic or inorganic matter, cannot be accumulated. The instantaneous rate of photosynthesis per unit area is limited by the flux of solar radiation and photosynthesis efficiency. Conversely, the instantaneous rate of decomposition per unit area grows with increasing biomass of heterotrophs and, provided oxygen for its burning is abundant, can be arbitrarily high. Accordingly, heterotroph functioning should be the primary source of internal perturbations in the organic and inorganic pools. This asymmetry can be compared to the asymmetry in the dynamics of atmospheric water vapor. While evaporation ("synthesis") is a slow, widely distributed process governed by solar energy, condensation ("decomposition") can occur at an arbitrarily high rate depending on the local value of vertical air velocity [33]. Condensation of water vapor stands behind such extreme weather fluctuations like hurricanes and tornadoes.

Given this asymmetry in the organization of synthesis and decomposition, the program of environmental stabilization should include compensatory reactions to disturbances from both autotrophs and heterotrophs. If one block functions erratically, the other can be damping environmental perturbations in the meantime.

First, at an elevated CO_2 plants may increase their P^+, which will lead to the appearance of excessive organic matter. (This part of the biotic response is often discussed in the literature in the context of "carbon limitation" of plants.) However, there is another side of the coin that is equally crucial: while P^+ is elevated above its equilibrium value, the decomposers (i.e., all the other organisms) *must ignore* the excessive organic carbon (which is their food) and keep the value of P^- unchanged. If the absolute value of P^- equally increases with P^+, no net sink of CO_2 may appear.

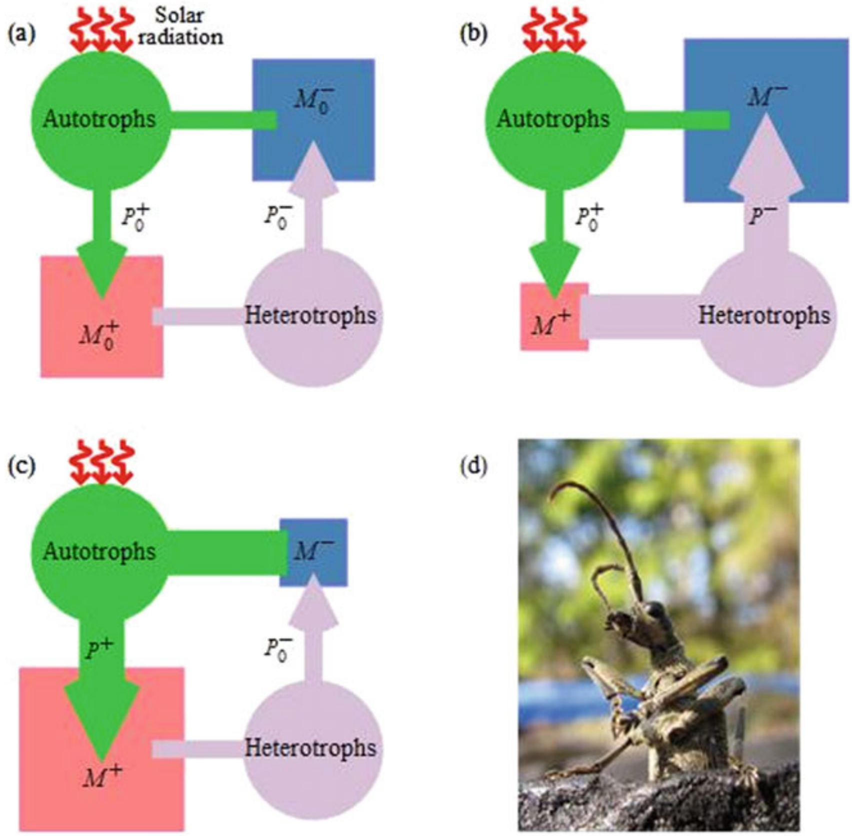

Fig. 1 A schematic representation of a closed ecosystem: autotrophs and heterotrophs synthesizing and decomposing organic matter at rates P^+ and P^-, respectively, and their environment represented by pools of organic matter M^+ and inorganic matter M^-; $M^+ + M^- = \text{const}$. **a** The equilibrium state with optimal magnitudes of $M^+ = M_0{}^+$, $M^- = M_0{}^-$ and coinciding rates of synthesis and decomposition $P^+ = P_0{}^+ = P_0{}^- = P^-$. **b** Ecosystem perturbed by an instantaneous rise in the rate of decomposition $P^- > P_0{}^-$: the organic pool $M^+ < M_0{}^+$ declined, while the inorganic pool $M^- > M_0{}^-$ increased. The compensatory reaction of the ecological community will be to increase synthesis rate $P^+ > P_0{}^+$ to diminish M^- and bring it back to the optimum. This genetically encoded compensatory rise in primary productivity upon addition of inorganic nutrients is interpreted as a nutrient limitation (Liebig's law) in disturbed ecosystems. **c** Ecosystem perturbed by an instantaneous rise in the rate of synthesis $P^+ > P_0{}^+$: the inorganic pool $M^- < M_0{}^-$ declined, while the organic pool $M^+ > M_0{}^+$ increased. The compensatory reaction of the ecological community will be to increase decomposition rate $P^- > P_0{}^-$ to diminish M^+ and bring it back to the optimum. This compensatory reaction of heterotrophs can take the form of an insect outbreak destroying the excessive "wrong" plant biomass perturbing the optimal ecological community structure (e.g., on tree plantations). **d** A representative of the family of longhorn beetles, some of which are serious pests of tree plantations. Photo by Anastassia Makarieva. Note that in an open ecosystem there must be a third, environmentally neutral reservoir present such that external disturbances in M^+ were not translated to M^- or vice versa (see Fig. 3 in [15])

Another opportunity to ensure a biotic sink of excessive CO_2 is for plants to keep P^+ unchanged (despite the allegedly limiting nutrient increased), while for the decomposers to reduce their consumption P^- in the meantime (despite the food abundance is unchanged). In this case, P^- decreases and the condition $P^+ - P^- > 0$ is met as well.

If, on the other hand, the inorganic carbon stock diminishes from the equilibrium amount $M^-{}_0$ to $M^-{}_0 - \Delta M$, then to restore the equilibrium we will need $P^+ - P^- < 0$ (decomposition exceeds synthesis). Again, two stabilizing responses are possible. Plants may keep P^+ constant despite the decreased amount of an allegedly "limiting" nutrient, while the decomposers raise P^- despite the is no increase in their food abundance. Alternatively, plants may reduce production P^+ while heterotrophs increase their consumption P^-.

This consideration of the mechanisms of environmental stabilization reveals two things. First, we can see that the stabilization of the carbon pool is a community-level reaction. It rules out the limiting principle as an explanation of a possible stabilizing biotic sink (or source) of inorganic carbon. Negative feedbacks of the biota cannot be explained assuming that plants are limited by inorganic carbon (CO_2), while decomposers are limited by organic carbon (food). A compensating sink or source appears in the result of nonrandom, *correlated* changes between the rates of synthesis P^+ and decomposition P^-, not in the result of *independent* changes in either P^+ or P^-. From the conventional biology viewpoint, when plants elevate their production P^+ while heterotrophs keep their consumption P^- unchanged despite the greater food availability, the latter "sacrifice" their immediate profit for the "common good" of a stable environment (see discussion in [21]). These complex reactions account for the fact that the persistence of organic matter in the ecological community is less a chemical property of molecules than dictated by the state of the community itself [40].

Since there are many chemical elements used by life and all of them must be regulated, the biota should be able to separately react to disturbances in each pool by changing the stoichiometric ratio of the synthesized organic matter. For example, if inorganic carbon is in excess due to an external environmental disturbance, while the remaining nutrients remain optimal, the biota should synthesize organic matter containing just carbon and no nitrogen or phosphorus and keep this excessive organic carbon in an inert state in a refractory pool [10]. A conspicuous example is the elevation of the proportion of carbohydrates that are difficult to digest in the organic matter of plants grown under conditions of elevated CO_2 [6].

The second conclusion is that in a stable environment production rates P^+ and P^- cannot be maximized simultaneously. In other words, it is not possible that the equilibrium value of $P_0 = P^+{}_0 = P^-{}_0$ is the maximum possible value of both P^+ and P^-. Any perturbation in a stable environment necessarily entails a nonrandom change in the production rates of either plants or decomposers or both. In some conditions, either P^+ or P^- must be higher than the equilibrium value. An optimal environment can, therefore, be defined as a stable environment where the *equilibrium* values $P^+{}_0 = P^-{}_0$ are maximized.

6 Rethinking Liebig's Law and Pest Attacks

Thus, that some groups of organisms can at times develop a higher productivity than in the long-term mean is not a proof that the environment has not been optimized for the ecological community as a whole. Environmental disturbances may bring about an increase in productivity in some species of the ecological community in very much the same manner as an infection of a mammalian body by viruses elevates its temperature and metabolic rate. Such an elevation of metabolic power above the optimal value is necessary to cope rapidly with the infection. It does not mean that the body's functioning is "limited" by the absence of viruses. Likewise, increased plant productivity in the ecological community can be an indication of environmental problems rather than well-being (Fig. 1b). Prolonged maintenance of the community in the state of such "environmental fever", e.g., by continuous fertilization, can lead to environmental and ecological degradation. For example, as long-term studies of tundra ecosystems indicate, continuous nitrogen fertilization results in a progressive loss of soil organic matter [30].

Attacks of insect pests on disturbed ecosystems represent a similar "fever" response of the heterotroph block of the ecological community to a situation when some kind of organic matter is present in excessive quantities (Fig. 1c). In natural ecosystems, a disturbance is followed by the process of succession that involves a nonrandom sequence of ecological events and implies a nonrandom species composition and energy flow structure at each stage of the recovery. Tree plantations, where the species composition does not match the genetic program of natural succession, represent a perturbed state. The "pests" try to destroy this unhealthy biota such that the normal succession process could start. Thus, while nutrient fertilization is perceived as positive for human-controlled biological systems, and pest attacks are perceived as negative, the two phenomena are in fact two sides of the same coin—the genetically encoded program of environmental regulation by the biota.

7 How is the Information About Environmental Regulation Maintained?

Suppose that we have an environmentally competent ecological community. The genetic program of species that compose this community encodes the behavior of individuals in such a manner that the community as a whole exhibits a compensatory reaction to any disturbance of its optimal environmental conditions. But the cumulative genetic program of the community is subject to errors that accumulate during its copying. With a low probability, a disruptive mutant ("gangster") species can appear which is productive enough to force out the normal ("regulator") species but at the same time is unable to regulate the environment. As soon as such a gangster invades the entire biosphere forcing out the normal communities, the biotic regulation ceases. Ultimately, the gangster perishes once the uncontrolled environment degrades to a state unfit for any life. How can be the biosphere protected against such gangsters? Below I provide a brief sketch of the main concepts.

We first need to formally define a gangster. As discussed above, a normal community reacts to a small environmental perturbation ΔM as $\Delta P = k\Delta M$, where $\Delta P \equiv P^{+} - P^{-}$ is the difference between the rates of synthesis and decomposition and ΔM is the deviation of parameter M from its optimum value M_0. Thus, in an optimal environment, the biochemical cycles are fully closed: $\Delta P = 0$. For the gangster $\Delta P = \text{const} \neq 0$: in other words, the environmental impact of the gangster is independent of the state of the environment within a relatively broad range of environmental conditions. For example, even when a resource is declining due to overconsumption, the gangster will continue to deplete it.

When the gangster starts colonizing the biosphere, the linear size L of the area occupied by the population of gangsters increases, while the environmental conditions in this area deteriorate. The condition for life to be protected against gangsters can be therefore written as

$$S_{\max} < S_E \tag{1}$$

Here $S_{\max}$ is the area colonized by the mutant by the time when its environment has degraded to a state unfit for the mutant: i.e., to a state when the gangster is no longer more competitive than normal individuals and $S_E \sim {L_E}^2$ is the total area occupied by life. When condition (1) is fulfilled, the mutant goes extinct before it succeeds to colonize the entire biosphere. Let us now estimate $S_{\max}$.

Suppose the mutant population originally occupying a small area of radius $L \ll L_E$ depletes its life-important resource (food) M (kg m^{-3}) at a rate ΔP (kg m^{-2} s^{-1}). The influx F of this resource into the area from the global environment is, in the linear approximation, $F = \Delta MD/L$, where D is turbulent diffusion coefficient and $\Delta M = M_l - M_0$ is the difference between the local and global concentrations of the resource. By equating $\Delta P = F$ (which means that the gangster's life is sustained by the influx of food from the yet undisturbed environment), we find how the relative degree $\varepsilon \equiv \Delta M/M_0$ by which the mutant destroys its environment depends on the radius L of the area that it currently occupies:

$$\varepsilon \equiv \Delta M/M_0 = \Delta PL/(DM_0); \tag{2}$$

$$L_{\max} = \varepsilon_{\mathrm{cr}} DM_0/\Delta P = \varepsilon_{\mathrm{cr}} D\tau/H. \tag{3}$$

Here, $\tau \equiv M_0H/\Delta P$ is the turnover time of resource M_0 found in the biosphere in a layer of thickness H due to its depletion by the gangster at a rate ΔP.

We can see from Eq. (2) that the gangster's environment deteriorates (the absolute magnitude of ε grows indicating deviation from the optimum environmental value M_0) with increasing linear size L of the area occupied by the mutant. As soon as ε reaches a critical value ε_{cr} (3), the mutant loses its competitive advantage as compared to normal individuals/communities that are able to drive the degrading environmental conditions back toward the optimum. This critical value of ε_{cr} in (3) determines the maximum size $L_{\max}$ of the area that can be colonized by the mutant. If $L_{\max} > L_E$, the biosphere is unprotected against mutants. Eqs. (1) and (3) illustrate those major factors that control the spread of gangsters in our example. First, other conditions being equal, a larger planet (with large L_E) is better protected against gangsters than a smaller one. Second, the larger the turbulent diffusion coefficient D of the physical environment, the greater territory can be invaded by the mutant before it goes extinct. Indeed, rapid mixing prevents local resource depletion and offsets local environmental degradation for the mutant. Third, the higher rate ΔP at which the mutant destroys the environment, the smaller area can be invaded by the mutant before it goes extinct. The narrower the range of environmental conditions within which the mutant remains competitive (the lower the value of $\varepsilon_{\rm cr}$), the sooner the mutant goes extinct.

Finally, perhaps the most important message to take from Eq. (3) is that the smaller the optimal concentration M_0 of resources in the biosphere, the smaller $L_{\max}$ and *the more protected life becomes* against gangsters/mutants. Resource abundance (a large value of M_0) undermines life stability providing opportunities to gangsters and lazybones. This is one of the key principles of biotic regulation.

8 Fundamental Constants Guarding Life on Earth

Let us now discuss some particular examples of the numerical relationships (1)–(3) using the available crude estimates of the relevant parameters. In the ocean, small unicellular organisms (phyto- and zooplankton) mostly perform the synthesis and decomposition of organic matter. Such organisms spread by the process of turbulent diffusion. Consider a zooplankton species consuming phytoplankton biomass at twice the mean global rate of decomposition P_0^-, such that for this gangster $\Delta P = P_0^+ - 2P_0^- \sim - P_0^-$. Thus, this gangster destroys its life-important resource (phytoplankton biomass) with a power coinciding in the order of magnitude with the mean power $P_0^\pm$ of the existence of life on Earth. This is about 100 GtC/year for the planet as a whole.

Global phytoplankton biomass, which is concentrated in the oceanic layer of thickness $H \sim 100$ m, is remarkably small: about 1 GtC [2]. For the turnover time $\tau = M_0H/\Delta P$ in (3) of phytoplankton we have $\tau \sim 10^{-2}$ year. A characteristic value of the turbulent diffusion coefficient on the oceanic surface is about $D \sim 10^3$ m^2/s $= 3 \times 10^{10}$ m^2/year. Assuming generously, that our gangster loses competitiveness as compared to normal species only when its food is *totally* depleted, $\varepsilon_{\rm cr} = 1$ in (3), using these values in (3) we obtain $L_{\max} \sim 3 \times 10^3$ km. Considering that the area of the Earth's ocean is $S_E = 4 \times 10^8$ km^2, we find that the maximum area occupied by the gangster, $S_{\max} = \pi {L_{\max}}^2$, is still one order of magnitude smaller than the total area occupied by the oceanic life, such that condition (1) is fulfilled even if not by a large margin.

This estimate uses an unrealistically high value of ε_{cr} corresponding to complete resource depletion. The value of ε_{cr} in (3) is related to the sensitivity of competitive interaction in the biota ε_b. This sensitivity characterizes the magnitude of a local deviation from the optimal conditions, which makes the local ecological community appreciably less competitive than its surrounding neighbors who continue to enjoy the optimal conditions. Based on various approaches, the value of ε_b was estimated to be in the range of 10^{-4}–10^{-3} [11]. That is, even a relatively small environmental degradation is noticed and acted upon by natural selection. Even if for the mutant this range is significantly broader, the value of ε_{cr} should nevertheless be appreciably smaller than unity. For $\varepsilon_b < < \varepsilon_{cr} \sim 0.1$ we obtain from (3) that a gangster can at maximum occupy one-thousandth part of the oceanic biosphere before it goes extinct.

Among the parameters entering Eq. (3), the ratio $M_0/\Delta P$ deserves a special consideration. Here M_0 (kg m^{-3}) is the resource concentration in the environment, in our example—phytoplankton biomass; ΔP is the rate at which the gangster can potentially destroy the biosphere. For $|\Delta P| \sim P^{\pm}$, the ratio $\tau = M_0H/\Delta P = M_0H\ /P^{\pm}$ characterizes the turnover time of the considered resource owing to its synthesis or decomposition by the biota, where M_0H (kg m^{-2}) is the resource abundance per unit area.

The maximum surface-specific rate $P^{\pm}$ of equilibrium life functioning (when the rates of synthesis and decomposition coincide) is determined by the flux of solar radiation and the biochemical efficiency of converting the energy of light into the energy of organic matter. Vertical size H of phytoplankton abundance is determined by the characteristic length of light penetration into the ocean. But how can turnover time τ be a fundamental property of life on Earth rather than a random value characterizing a given state of the biosphere?

The fundamental nature of τ follows from the universal biochemistry of life, which in its turn dictates a universal metabolic optimum rate of existence for all living beings. The metabolic rate per unit of living matter (the rate at which organisms consume energy) is broadly universal at around $q_0 \sim 4$ W/(kg live mass) $\sim 4 \times 10^{-2}$ W/gC for a vast majority of living beings from bacteria and plants to higher animals [32]. Total biomass of all phytoplankton cells per unit area, M_0H, is determined by the condition that their cumulative energy consumption does not exceed the biotically available energy flux $KP^{\pm}$, where $K = 42$ kJ/gC is the universal energy content of organic matter:

$$M_0Hq_0 = KP^{\pm};\ \tau \equiv M_0H/P^{\pm} = K/q_0 \approx 10^6\ \text{s} = 3 \times 10^{-2}\ \text{year}. \qquad (4)$$

We can see from (4) that the turnover time of live biomass in the ocean, which depends on primary productivity and live biomass abundance, is equal to the ratio of two fundamental constants: the energy content of organic matter K and the universal metabolic rate of living beings q_0. The optimal ambient concentrations of life-important elements like carbon (both dissolved organic carbon and CO_2), nitrogen, phosphorus, etc., are linked to the optimal concentration of living cells that is determined by H, $P^{\pm}$, and τ.

The above considerations are aimed to illustrate that a particular set of values of fundamental parameters of Earth and life itself plays a crucial role in life stability. Similar to how a particular value of the fine-structure constant—a fundamental physical constant—allowed for the formation of the main chemical elements used by life, the long-term persistence of life on Earth is contingent upon several major parameters of our planet and life itself. We still do not know many of these critical parameters. But clearly, their investigation will shed light on the principles of life organization as well as on many important problems of modern humankind.

9 Life as a Potential Destabilizer of the Environment: No Genetic Adaptation Possible

A crucial property is the ability of life to transform the environment more rapidly than any geophysical processes. Transpiration of water by terrestrial plants amounts to about one-tenth of total solar power absorbed by the planet. (For comparison, global atmospheric circulation power is about an order of magnitude smaller—only about ~1% of solar power.) Likewise, the global rate of synthesis and decomposition of organic matter $P^{\pm}$ is several orders of magnitude higher than the rate of any geophysical processes. Net primary productivity of the biosphere is about 10^2 GtC/year—compare this with the rate of carbon emissions from the Earth's core that occurs with an average rate of 10^{-2} GtC/year, i.e., are ten thousand times slower.

In other words, life itself is the most important potential destabilizer of the environment—a fact that has not been emphasized in the studies of Gaia where the focus is instead on the abiotic environmental perturbations. In the original numerical Daisyworld models, the main environmental parameter controlled by the biota was albedo (a static parameter) rather than concentrations of life-important elements that strongly depend on the system's dynamics.

In biotic regulation, compensation of abiotic disturbances (which are central to both Gaia and Neo-Darwinism) is a by-product of the inherent process of compensating for the more significant fluctuations within the biota itself. Biotic processes are significantly more powerful than abiotic processes. Being able to compensate for the internal life-induced disturbances, the biota is automatically able to compensate for all the weaker disturbances like the geophysical processes.

On the other hand, the short time scale of potential self-degradation of the biota given by turnover time τ of major life constituents testifies that genetic adaptation to changing environmental conditions has not played a significant role in life's survival. This is because new genetic information (which could possibly help the organisms in a changed environment) takes a very long time to arise. A characteristic time of evolutionary change is about $\tau_{sp} \sim 3 \times 10^6$ years—this is the meantime of species existence, after which a new species possessing new properties can be produced from the old one (Table 2). So if the biotically controlled environment fluctuates on a time scale of $\tau \sim 10^{-2}$–10^2 years (Table 2), $\tau \ll \tau_{sp}$, no genetic adaptation can take place.

Table 2 Some key biological and environmental time scales

	Time scale (years)	Comments
Biology		
Metabolic turnover time τ	3×10^{-2}	$\tau \equiv K/q_0$, where $K = 4.2$ kJ/g is the energy content and q_0 ~ 4 W/kg is the characteristic mass-specific metabolic rate of living matter, see text
Genetics		
Characteristic species duration τ_{sp}	3×10^6	Leopold [24], Makarieva and Gorshkov [31]
Time scale of genetic information "melting" τ_m	3×10^8	$\tau_m \equiv \tau/(\nu\, n_d n_p)$, $\nu \sim 10^{-10}$ (n.p. div)$^{-1}$ is the probability of mutation per nucleotide pair (n.p.) per cell division (div), $n_p = 1$ n.p., $n_d = 1$ div; it is assumed that living cells on average divide and copy their genetic information each $\tau = 3 \times 10^{-2}$ year. In time τ_m , mutations will have occurred with a probability close to unity at all nucleotide sites in all genomes. In the absence of natural selection, this would erase all genetic information
Environment		
Carbon turnover time via inorganic and metabolically inactive organic pools τ_c	10	$\tau_c \equiv M/P$, $M \sim 10^3$ GtC is the store of inorganic (atmosphere) or organic (soil, wood, dissolved organic matter in the ocean) metabolically inactive carbon, $P \sim 10^2$ GtC/year is the global rate of biological synthesis and decomposition
Surface fresh water turnover time on land via runoff τ_w	10	$\tau_w \equiv W/R$, $R = 2.5 \times 10^4$ km^3/year is the global river runoff, $W \sim 2 \times 10^{-4} \times 1.4 \times 10^9$ km^3 is the surface fresh water pool assumed to be of the order of 0.02% of oceanic water
Ocean warming by 10 °C by full sunlight absorption τ_o	30	$\tau_o \equiv H_o c \rho \Delta T/I$, where $H_o = 3.8$ km is the mean oceanic depth; $c =$ 4.2 kJ/kg/ °C is the specific heat capacity of water; $\rho = 10^3$ kg/m^3 is water density; $I = 150$ W/m^2 is the mean solar radiation flux absorbed at the surface; $\Delta T = 10$ °C

Biotic regulation offers a new interpretation for the evolutionary changes known from the fossil record. Random changes of the genetic program of biotic regulation in most cases produce defective mutants, but in some very rare cases can produce improvements in the efficiency of biotic regulation. RNA viruses that have mutation rates six orders of magnitude higher than the DNA-based life [14] generate new meaningful genetic information. Basic calculations show that the intraspecific genetic polymorphism generated by mutations (errors) during DNA copying is insufficient to describe the observed rates of generation of new genetic information in the biosphere [31].

The new genetic fragments generated by viruses are then “offered” to other species in the biosphere via horizontal gene transfer along this “evolutionary highway” from viruses to the rest of life. If upon incorporation into the genomes of the “existing” species such fragments make the biotic regulation program more efficient, new species may evolve and compose a new community with a new program of biotic regulation. Since a new program can imply a new set of optimal conditions, such an evolutionary change can entail a major environmental change—not vice versa. Thus, the environment will change, but remaining under biotic control at all times. The spontaneous evolution of life drives environmental change. The most dramatic shifts of this type should be very rare: one possible example is the transition from anoxic to oxygen-breathing biota. More regular evolutionary events like the appearance of new species in a given ecological community can be interpreted as minor improvements in the biotic regulation program.

10 Life on Land

Life on land differs from oceanic life in several crucial aspects. First, life on land could originate several times from oceanic life. If the first local ecological communities on land were poorly organized, they could perish without driving the whole life on Earth to extinction. In contrast, oceanic life originated only once.

Second, diffusion of many life-important chemical elements in the terrestrial biota occurs much more slowly than in the ocean—because of the high viscosity of soil it occurs by molecular rather than turbulent diffusion. For example, for soil nitrogen and phosphorus the diffusion coefficient is less than 10^{-2} m^2/year, i.e., D in (3) is practically zero.

On the other hand, the locomotion of large animals on land is less costly than in the ocean. Large animals are able to consume biomass at a high rate and to migrate quickly over large areas. Their migration rate (analogous to diffusion coefficient) can be very large. Also, plant biomass on land is about three orders of magnitude larger than in the ocean (where it is of the order of 1 GtC), which results in a higher value of carbon turnover time $\tau \ll \tau_c \sim 10$ years (Table 2). Accordingly, during its invasion the gangster on land will have a significantly larger resource than in the ocean.

These considerations show that life on land is potentially unstable with respect to the destabilizing impact of large animals: they are the main candidates for terrestrial gangster species [34].

Ecological communities on land evolved, perhaps by trials and errors (the latter leading to extinctions), several measures against such vulnerability. While the store of biomass on land is very large, it mostly consists of biologically unavailable wood. Wood becomes available for decomposition only after the tree is dead. Wood in a living tree is defended biochemically against being eaten by animals. Among the many millions of biosphere species, only a few are able to destroy living wood and kill trees. Large animals normally consume no more than about 1% of primary productivity in undisturbed terrestrial ecosystems like forests: i.e., the resources available for them are much smaller than the total biomass store (unlike the situation in the ocean).

Humans are a gangster species, but an unusual one. Unlike the "normal" gangsters who based their invasion on the available stores of resources, humans, owing to our ability to accumulate cultural heritage, learned how to use fire. We thus could increase the available resource abundance and increase turnover time τ in (3). This allowed for a global expansion of our species in the past. The spread of humans with their primitive agriculture impaired the regulatory capacity of the terrestrial biosphere, but did not fully destroy it. Humans still did not eat wood and depended on soil fertility (low D for soil biogens in (3)), such that when the natural ecosystems were totally degraded in one place, humans went away and let them to recover.

However, recently the store of energy resources available to our species grew by additional one-two orders of magnitude with the discovery of fossil fuels—10^4 GtC compared to 1 GtC of live biomass in the ocean or ~10 GtC of edible biomass on land. Using this energy, humans have almost completed the colonization of the entire biosphere simultaneously destroying all natural ecosystems everywhere in the world. Humans have been able to do it very quickly—apparently, before our environment has deteriorated to a state prohibiting further expansion.

In the now globally disturbed terrestrial ecosystems, synthesis and decomposition proceed in an uncorrelated manner, such that carbon pools can be depleted or doubled in just a few years. An example of such decoupling is soil erosion (i.e., the depletion of the soil organic carbon pool)—depending on the intensity of anthropogenic pressure, soil degradation occurs on a time scale from 1 to 10^3 years. If in the past a degraded agricultural field had a chance to be recovered via being colonized by natural species, now, when the natural ecosystems are globally lost, and our soils fully degrade, they will not have such a chance. The same concerns other life-essential resources like freshwater on land that is characterized by a transient store (Table 2). Water cycle is heavily impacted by the presence of natural forests and deteriorates if those are replaced by plantations [35, 41].

11 Conclusions

Functioning of living objects depends on environmental concentrations of life-important chemical elements in organic and inorganic form. Their pools are finite and their turnover times are small on the evolutionary scale. Thus, a genetic program of environmental sensing and control must have been included in the minimal genetic information kit that had differentiated life from non-life.

We have considered what environmental characteristics the genetic program of environmental regulation by life must encode to make this program maximally genetically stable (Table 1). The conclusion is that the environment must be such that when left without regulation it locally degrades at a maximally possible rate. This means that the local abundance of energy and matter resources and their global mixing must both be small. In such a case, any mutant not contributing to the "common good" of keeping the environment stable will deteriorate its own local environment and perish before it could have conquered the biosphere.

This conclusion formulated by Gorshkov [13] forms the basis of the concept of the biotic regulation of the environment. Other authors later arrived at similar conclusions in different, but related contexts (although not in the original Daisyworld studies). Generally, maintenance by natural selection of any property that restricts individual performance like resource consumption for the "common good" requires that the resources are limited and their global mixing is small.

Kinzig and Harte [21], see also [17], showed that limited resources in spatially structured environments with little mixing favor "less voracious" microbes (the "strategists") who, in contrast to the "voracious tacticians," sacrifice the maximal possible rate of resource consumption to the long-term persistence. The implication is that in stable ecosystems consumption of the resources by heterotrophs does not proceed at the instantaneous maximal possible rate (which can be infinite depending on heterotroph biomass).

Studies of programmed senescence found that a very long lifespan is associated with the production of numerous progeny and thus resource depletion is selected against under conditions of low resource abundance and low mixing, favoring instead a shorter lifespan and programmed death [25, 42]. In this context, mixing also includes the dispersal of living individuals. Interestingly, in their critique of the programmed aging concept Kirkwood and Melov [23] did not present any objections against the maintenance of such a program in spatially heterogeneous environments with limited resources and limited dispersal but called such conditions "special."

However, rather than being special, strict limitation of energy consumption and mobility is in fact at the core of life organization. Getting their energy from massless solar photons plants do not need to move [14]. Any local environmental perturbation by an incorrectly functioning tree will be inherited by its progeny. Furthermore, since energy consumption by autotrophs per unit area is limited by the incoming solar radiation, natural selection for maximization of mass-specific metabolic rate will lead to a proportional decrease of area-specific plant biomass store thus reducing τ

in (3). While oceanic and land biota have comparable areas and equal total net primary production (50 GtC/year), there is only 1 GtC phytoplankton compared to about 15 GtC of green leaves [2]. This is because the small phytoplankton has metabolic rates about ten times higher than the larger green leaves, see [32] and Fig. 1 in [15].

It might be instructive to discuss how the original Daisyworld model could be reformulated to make transparent the above fundamental patterns. In the Daisyworld, a constant global temperature under changing solar luminosity implies that any given value of luminosity determines a fixed steady-state ratio of black to white daisies [44]. The same effect would be reached if one seeded the entire planet with just one species of daisies able to change their color depending on temperature—darkening when it is cold and whitening when it is hot. It is clear then that if the solar luminosity remains constant or changes very slowly, this property of temperature-dependent color change will be subject to genetic decay. Daisies of the same brightness as the "regulators" but lacking the ability to change color will ensure the same optimal global temperature. They will not have to invest resources into maintaining the temperature-control mechanism. Using the spared energy to reproduce more vigorously, they will outcompete the regulators globally thus doing away with the planetary temperature homoeostasis. Then when the solar luminosity ultimately changes, slowly as it will, the biota will be unprotected.

This once again illustrates that there cannot be a genetic program for regulating a physically stable environment. The environment must be rapidly changing toward unfavorable life condition if left without biotic control [34]. For example, the temperature "regulators" will have an advantage if the temperature of the abiotic environment fluctuates widely around the optimum (e.g., during the day). Then by changing the color it would be possible to keep the local temperature close to the optimum at all times and have advantage over those who cannot regulate. The role of the time scale τ (3) of resource depletion (environmental deterioration) in this case will be played by the time scale of the characteristic local temperature fluctuations.

Natural ecosystems exert a strong control on local surface temperature, via transpiration on land and control of water transparency in aquatic ecosystems [20, 39], as well as via cloud formation [16, 41]. The presence of an ocean with its nearly infinite store of atmospheric moisture results in a major thermal climatic instability: the concentration of water vapor, the major greenhouse gas, doubles per every ten degrees of temperature rise, thus increasing the greenhouse effect and further increasing the temperature. This intrinsic physical instability, along with abiotic temperature perturbations, creates favorable conditions for the maintenance of biotic temperature regulation by natural selection. (It cannot be excluded that the ocean itself might be of biogenic origin [14]). The problem why despite the destabilizing moisture feedback the Earth's climate remains stable has not received considerable attention in atmospheric sciences even if it is key for understanding Earth's climate [3], see also Fig. 2.

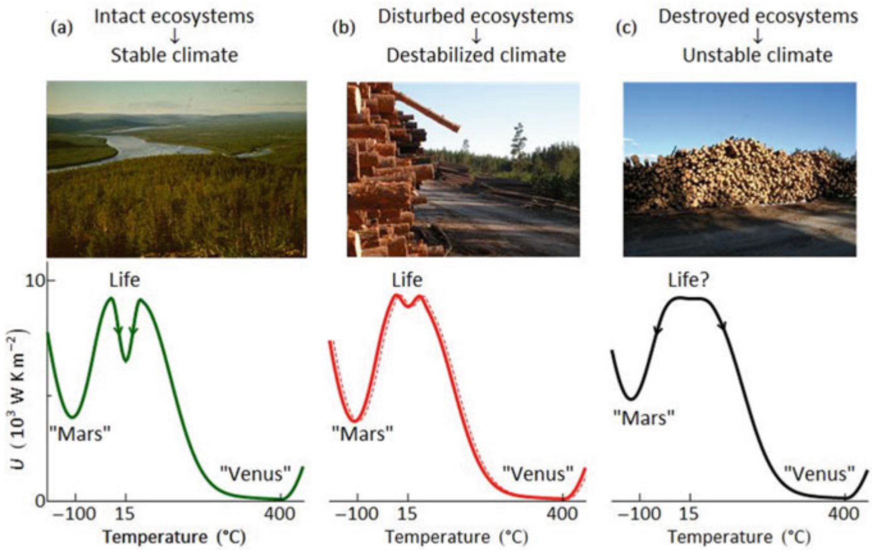

Fig. 2 Climate stability, carbon emissions and biotic regulation. Potential function U (W K m^{-2}) for the thermal stability of the Earth's climate versus planetary temperature T, $dU/dT = -c_s dT/dt$ (W m^{-2}), where c_s is heat capacity per unit surface area, t is time (after [12]. The slope of the U curve (dU/dt) shows how fast the climate system tends to return to a stable state when perturbed. The steeper the curve, the greater the time it will take for a given radiative forcing $F > dU/dt$ (W m^{-2}) (or the greater the forcing required for a given time period) to drive the climate away from the stable state. **a** The relatively unperturbed (preindustrial) biosphere is characterized by the deepest central pit (maximum stability) corresponding to modern global mean surface temperature (+15 °C). The left and right stable states correspond to uninhabitable Mars- and Venus-like climates at around −100 °C and +400 °C, respectively. **b** On modern Earth with the biosphere significantly perturbed, the life-compatible potential pit is shallower. This means that any forcing in a given time, including radiative forcing from excessive carbon dioxide, will lead to a greater deviation from the preindustrial stable state than it would in an unperturbed biosphere. The dashed line shows global warming estimated neglecting changes in climate stability—the central pit just shifts to the right by about 1 °C. **c** Totally destroyed natural ecosystems correspond to the disappearance of the life-compatible potential pit. In such a case even with a negligible external perturbation, or complete lack thereof, the climate spontaneously and irreversibly can precipitate to either Mars-or Venus-like states, with greenhouse gas emissions making the latter outcome more probable. Photos by Victor Gorshkov (**a**) and Anastassia Makarieva (**b**, **c**)

Since carbon dioxide is needed for the biotic matter cycle and is at the same time a greenhouse gas that affects temperature, the biotic controls of temperature and productivity could have come into conflict. The presence of atmospheric moisture as a major substance controlling both albedo and greenhouse effect on Earth allows life to avoid possible conflicts decoupling temperature and productivity controls—rather than the former being a by-product of the latter as sometimes proposed (e.g., [37]. In other words, if a favorable for productivity CO_2 excess would entail an unfavorable increase in temperature, this could be compensated for via a biogenic reduction in the greenhouse effect or increase in albedo, i.e., by the biotic control of moisture.

The fact that only physically unstable environment can be regulated by the biota has direct implications for the humanity concerned about global change. This means that once the regulatory mechanisms (natural ecosystems) are destroyed, the environment will rapidly degrade to an unfavorable state irrespective of whether humans directly contribute to environmental deterioration, e.g., via carbon emissions, or not.

If the biotic impacts are responsible for the apparent thermal stability of the Earth's climate, the global destruction of natural ecosystems should have resulted in a decrease of this stability and growing climatic fluctuations on a variety of timescales. In the absence of external forcings, such destabilization alone could have produced either global cooling or global warming. Carbon dioxide emissions should have pushed the system toward global warming. However, even if the emissions stop and all the excess carbon is removed from the atmosphere, climate stability will not be regained as long as the natural ecosystems continue to be destroyed.

The common neglect of the genetic program of climate control by life has led to a troubling situation when natural ecosystems are evaluated in the most primitive terms according to their mean steady-state properties. Forest recovery is exclusively discussed in terms of carbon storage or the mean local temperature impact via albedo and transpiration [43]. But the main issue about natural ecosystems is not what they are but how they react to environmental perturbations. In simple terms, natural forests neither cool nor warm the Earth. They warm it if it is too cold and cool it if it is too warm compared to the optimal steady state thus ensuring climate stability, Fig. 2. That the precise biological mechanisms of this control have been so far too complex for us to find out, does not mean that they do not exist or that we will be spared if they disintegrate.

Finally, forest ecosystems consist of some of the longest lived species—trees. Once destroyed, they will recover their function through the natural process of forest succession in hundreds of years from now. Thus tree planting by itself, while having a wide appeal due to its conceptual simplicity, does not offset or compensate the destruction of natural forests, even if it could make total wood loss zero or even lead to a biomass increment. Tree plantations and young regenerating forests are not environmentally functional as they lack the needed genetic information about how to control climate. Diverting resources and attention from the protection of natural forests, tree planting may even have an adverse effect on climate stability. However, it can make a huge positive impact if the newly planted trees are cut instead of natural forests thus reducing anthropogenic pressure on the latter. Also, tree planting and generally restoration of land fertility can allow people to grow more food on restored lands without extending agricultural lands into the extant natural forests.

To conclude, contrary to what is sometimes opined in the Gaian context (e.g., [9, 22], whether or not life regulates its environment is not an academic issue of little relevance to the current climate problems of the humanity. Neglecting or, conversely, taking into account this regulation implies distinct, sometimes opposing strategies of mitigating global change and preserving ourselves as a species. There is urgency associated with the fact that biotically unregulated environment should be inherently unstable and rapidly degrade. If science is to contribute to preventing the global ecological and environmental collapse rather than facilitating it, a multidisciplinary effort is required to build a coherent and comprehensive picture of life–environment interactions.

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Resilience Thinking: Push-Start of a New Enlightenment in the Light of the Sustainability Paradigm

Peter A. Wilderer and Michael von Hauff

Abstract Resilience Thinking stands for a method capable of securing the continuation of entrepreneurial success, as well as of continuing well-being of societies including individual families. In essence, Resilience Thinking favours sustainable development of societal and economic systems in an ecological context. It is rated as the cognitive counterpart to the self-regulation properties inherited in ecological systems. The process which is key to Resilience Thinking is the adaptive cycle. This cycle needs to be continuously kept revolving in response to changes within and outside of the system under consideration. Initiation and control of the adaptive cycle require permanent monitoring and readiness to give up on obviously outdated practices. Stubbornness of private and public management and even worse: provision of subsidies bear the risk to end up in a catastrophic situation. Adoption of the principles of Resilience Thinking could even be seen as the first signs of a new Enlightenment.

Keywords Resilience · Anthropocene · Ecosystem adaption · New enlightenment · Sustainable development

1 Introduction

The authors of the recent report to the Club of Rome, Ernst Ulrich von Weizsäcker and Wijkman [14], investigated the current situation of the human-dominated world—also known as the "Anthropocene". According to their diagnosis misbehaviour of humankind at large is a considerable reason for a very dangerous breakdown of

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societal, economic and environmental stability on Earth. Eventually, the authors come to the conclusion that the world needs a "New Enlightenment" as a means to contribute to the strengthening of the balance between society, economy and nature, the balance between production and consumption, as well as the balance between gains of scientifically based advanced knowledge, and efficient transfer of that knowledge to the general public.

Today, the willingness to use concrete measures to implement sustainable development is still rather low, although there are many concepts and measures that are outlined in the second part of our paper. Balancing the demands of nature and society, of local communities and central governance, of the dealing with technical and societal risks, of protection and conservation of the Earth system—just to name a view—has been the main topics of the workshops organized since 2008 by the International Expert group on Earth System Preservation (IESP: https://www.ias.tum.de/iesp/whoisiesp/). In general, fostering the resilience of the Earth System which humankind is a part of (see appendix of this chapter) is in need. Engagement in the exploration of the consequences of human misbehaviour and resilience of societal, ecological and economical subsystems—human health included—was a logical further step of the IESP´s program.

In the following, we invite the readers to join us on a journey through the world of resilience thinking. Our intention is to stimulate sustainable development hand in hand with the evolution of a new enlightenment by bringing together scientifically sound analysis and recommendations for practical action in responsibility for the whole.

2 The Essence of Resilience

The term "resilience" is derived from the Latin "*resilire*" (jumping back). It refers to the ability of a system—for instance, an ecosystem, a societal system, a political system or just a family or a company—to continuously adapt to changing ambient conditions and still retain its basic function an structure, identity and integrity [13]. Thus, resilience is to be understood as the property of a system in permanent evolution where the governing processes are dictated by a great number of influences from outside and from inside of the system. The system itself consists of a multitude of components interacting dynamically with or independently from each other, particularly when exposed to disturbances.

To introduce some of the basic principles of resilient thinking we use in the following a very simplified model of the complex interactions of a system with its environment. For this particular reason, we have chosen the so-called "Ball in the Bowl" model described by [13]. Figure 1 shows the cross-section of the bowl representing the particular environment under consideration. The ball resting at the bottom of the bow, called the point of attraction, represents the system under consideration. Triggered by modest changes of the ambient conditions (called: perturbation or disturbance such as a power failure) the systems gets temporarily driven away

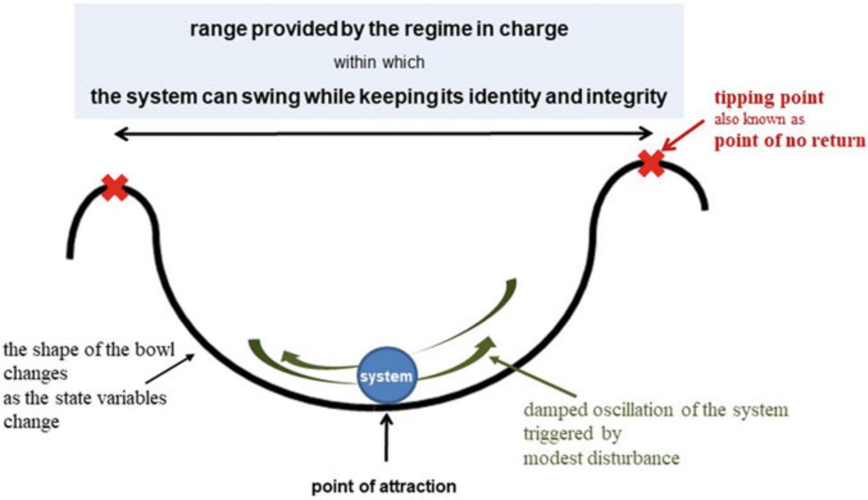

Fig. 1 One-dimensional model of resilience: The bowl is shaped in width, depth and curvature by state variables such as climate, biodiversity, resources availability, economy, governance, political leadership, society. (Graphical presentation adopted from Wilderer and von Hauff [15])

from the attraction point. Once the disturbance has vanished the ball returns in an oscillating manner to the attraction point. The sequence of displacement caused by perturbation and return to the rest symbolizes the dynamic properties of resilience.

Resilience is a balanced state. Resilience thinking is a concept dedicated to the achievement and maintenance of the status of resilience. It is a means to deliberately develop an understanding of the relationship between causes and effects. It enables responses as a matter of good practice. Resilience thinking is, thus, a measure to investigate how interacting systems of people and nature can be best managed in the face of disturbances, surprises and uncertainty. It ensures a sustainable supply of the essential ecosystem services which humanity depends on [1].

Historical evidence suggests that—even in times before humans appeared on Earth—the Earth system was exposed to often dramatic changes of ambient conditions. For instance, the outbreak of volcanoes and changes in solar radiation caused the Earth to cool down for centuries. Glaciation was followed by extreme global warming. Some of the organisms living on Earth could not stand either extreme cold or extreme warm climatic conditions and disappeared. But life as such continued to exist. Life demonstrated the ability to adjust and persist. It demonstrated resilience.

Eventually, *Homo sapiens* appeared on Earth and became part of the ecosystem. Humankind, from early on, modified actively environmental conditions—for instance, by slash-and-burn [6], and continues to do so until today be it for the better or for the worse. From the beginning on human kind demonstrated also the ability to adapt to very different environmental conditions, be in the tropic, the deserts and in the arctic. The sentence "*Tempora mutantur et nos mutamur in illis*" (times change, and we change with them) supports this assumption. It refers to the changes, time brings about. The phrase was borrowed from Ovid´s poetry by Caspar Huberinus in 1554. Based on modern developments the sentence should re-formulated, however. There is no automatism that drives us, human beings, to change in times. Many of us are known to stick to what we are used to or what was successful so far. As we explain in the following, this retrospective approach called "business as usual", is dangerous. We better should phrase that sentence to: "Times change, and we must change accordingly".

Based on the rapid increase of knowledge and advances in technology "times" change nowadays unprecedentedly fast and substantial. Under those conditions, some of our fellow humans obviously struggle with appropriate adaptability. Conservation of the past is often considered more important than risking the unthinkable. The Earth system is highly dynamic in nature and so is economy, technology and society. It must not be considered a museum, though. Conservation areas are an example of this backward-oriented approach.

Even in former times people, particularly the elders, were reluctant in departing from the assumption that their so far successful doing is the benchmark for the young generation. "The old is gone, the new has come" (Corintians 5:17) is not a rejoicing wisdom shared by those who were successful in the past. It rather is a never-ending matter of frictions and disputes between the young and the elder generations. Or as Machiavelli wrote in his book "The Prince": "Nothing is more difficult to achieve, more risky in realization, and more uncertain concerning success than to introduce a new order, since the innovator has as an enemy those who were successful under the old order, and receives only luck-warm support by those who could profit from the new order".

With respect to resilience of businesses, political systems and coherence of society reluctance against evolution is a significant problem. The overarching concept of resilience thinking might be considered as a means to overcome such problems.

3 Resilient Systems Under Threat

As already elaborated above, the concept of resilience refers to social–ecological systems capable to withstand perturbations, to continually rebuild and renew itself. Moreover, it provides a framework for analysing and actively responding to a changing world facing a multitude of unique uncertainties and challenges [1].

In this respect, it is important to understand the difference between slowly and abruptly developing changes of state variables. State variables may develop slowly over time. So, they are often overlooked and thus become eventually a threat. With reference to the "Ball in Bowl" model, slow-developing threats might lead to the shallowing the bowl's curvature (Fig. 2). Even slight displacements of the ball (system under consideration) away from the point of attraction could drive the system close or even over the tipping point to the right side of the bowl.

The examples described in the subchapter entitled "The subsidy trap" illustrate the threats associated with not realizing, even ignoring the effects of slowly developing

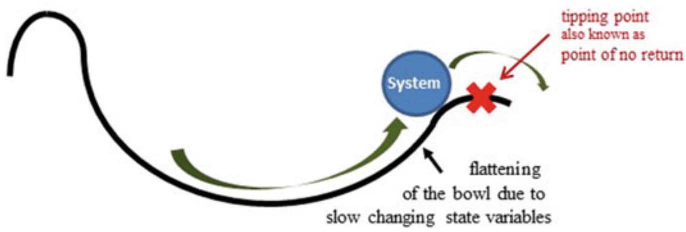

Fig. 2 Slow changes of state variables may conceptually be visualized by flattening of the basin. This bears the danger that the system even under modest perturbation gets driven close to and even over the tipping point

state variables. In a figurative sense, they may cause flattening the shape of the bowl. Slow changes in market demands, consumer´s preferences, as well as innovative communication and information possibilities are some examples of the reasons for causing the "the bowl to flatten". Displacement of the "ball" away from the point of attraction could readily drive the ball (the system under consideration) over the tipping point.

Figure 3 visualizes the response of a social–ecological system to major threats such as an outbreak of pandemic infection of monoculture forestry or agriculture, bankruptcy of a company, breakdown of the financial system, sudden change of the political agenda or a civil war. Such catastrophic events might drive the systems of concern to and over the tipping point into a world governed by a regime, different from what was so far familiar to the agents. It will definitely offer surprises but also challenges. Will the new regime be better or worse? The answer to this question depends very much on the standpoint of the observer. To avoid transforming to any adjacent regime requires the realization of early warning signals and, thus, future-oriented actions including the welcoming of the new world of chances.

As an example, the breakdown of the Soviet Union led to the liberation of the former satellite States and to the reunification of Germany. The change of the regime was welcomed by some but caused loss of the working merits, pensions and pride

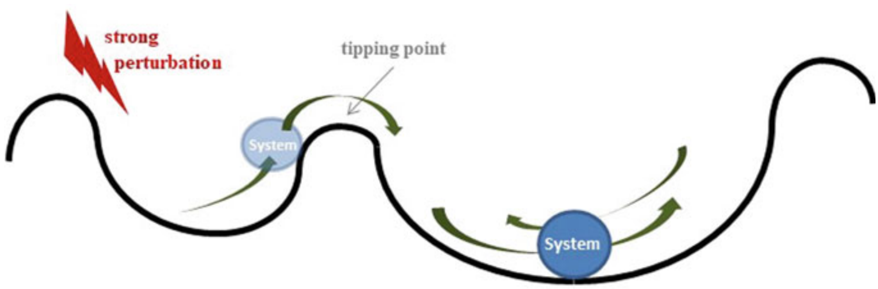

Fig. 3 Caused by a strong perturbation the system is forced to slip over into an adjacent basin of resilience while losing its former but gaining a new identity and integrity

particularly of elderly people in East Germans. The oscillation of the pros and cons in the Eastern part of Germany lasts longer than originally expected. After almost three decades, the state of full eco-social equality and resilience has not been established yet, as the current right-wing populism clearly demonstrates.

4 The Adaptive Cycle

At this point, the question arises which actions should be taken in order to make sure that the system of concern remains close to the point of attractions symbolizing the state of resilience—or at least keep the system away from the tipping point. Buzz [8], the godfather of resilience science, was the first who gave answers to this question. Walker and Salt [13] elaborated the graphical model suggested by Holling.

The basic message is: In order to maintain resilience of socio-economic systems, a company, for instance, it is crucial to govern the system through a continuously revolving cycle of exploration, evaluation and decision making.

In living system, particularly in ecosystem, self-regulation processes on the community level provide the ability to resist collapse and even more importantly to adapt to changes in ambient conditions. Ecological evolution is not cyclic as Walker and Salt clearly demonstrate in their book (2006). In contrast, self-regulation processes play only a limited role in societal systems. They are primarily replaced, controlled and affected by cognitive interventions executed by individuals, the society as a whole and by governance. Instead of trusting on self-regulative processes, it is the responsibility of the human society to respond to perturbations and disruptions on the basis of general ethics and with wisdom and creativity.

Holling's graphical model of intertwined loops considers a continuously repeating sequence of processes required to anchor a small or medium-size enterprise or a group of companies in a sustainable state of resilience. The model distinguishes four major phases:

Start-up
growth and expansion
consolidation and conservation
release (4a) or continue business as accustomed to (4b)
reorientation and reorganization.

A simplified version of the loop model is presented in Fig. 4. In the chosen case study, an entrepreneurial system is addressed.

The cycle begins with the installation of a new leadership committed to drive the company into a considerably profitable direction (Step (n + 1) 1). "n" stands for the number of former cycles of adaptation. As the output of the company shows a positive response the company starts to grow in size and to expand its market share (Step (n + 1) 2). Gradually the company stabilizes its position (Step (n + 1) 3). The leadership team as well as the employees enjoy success and recognition by the local and even international market. Meanwhile, the government considers the company

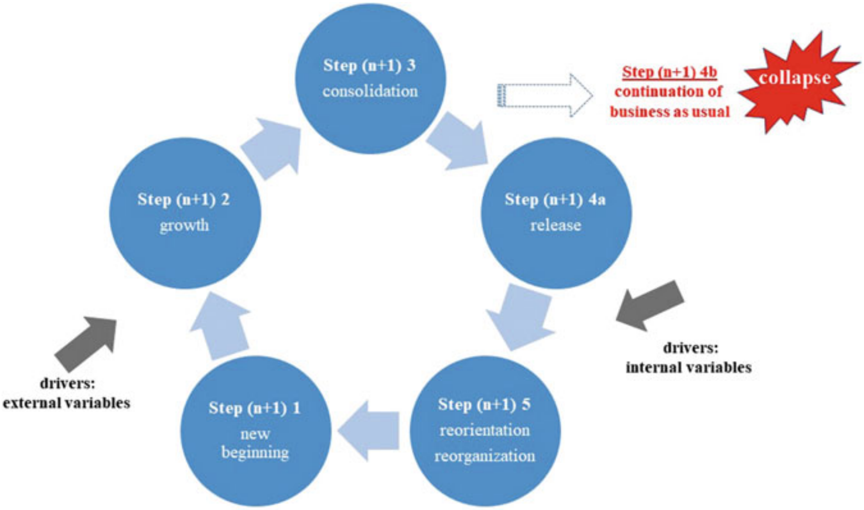

Fig. 4 Graphical representation of the adaptive cycle

as a major factor of economic attraction and as an important employer. The latter is also positively recognized by the respective labour union.

Courage to release business-as-usual practices and to enter into a process of reorientation and reorganization keeps the system in the state of resilience

Drivers of this development are external variables, which are gradually evolving. Some examples may illustrate such external drivers: innovative production schemes, behavioural changes and alternative preferences of buyers and consumers, change of distribution management, of taxation, money exchange rates, governmental regulations and so forth. Moreover, the management of the company is confronted with internal variables such as foresight, courage, responsibility. If clever, the management has realized new possibilities of financing, production methods and sale opportunities. Subsequently, a complete change of the product portfolio is under dispute. Relocation of the company is taken into consideration although the local government, the employees and the labour union protest heavily against such planning. Discussions follow discussions. The German "discussion culture"—presumably to be understood as the aftermath of the liberal education of the 1968s—is in full progress. The generation of that time acts reluctantly when it comes to the point of decision making. Instead, people are eager to discuss endlessly options over and over again. Time is wasted. Obviously, we do not have a lack of ideas of solutions, but a tremendous lack of getting solutions implemented. We lack a rigorous, highly effective "decision making culture" based on general ethics, on the principles of sustainable development and in line with the resilience paradigm. However, the contemporary young generation is fed up with the lack of courage expressed by the generation currently in leading positions. Greta Thunberg with her "Fridays for Future" initiative is just an example. Likewise, a multitude of young entrepreneurs in various fields of technology, including agriculture, are spearheads of a new generation of actors dedicated to paving the way towards a resilient, sustainable future.

Back to our case study, the owners of the company are forced to make decisions of significant implication: Release or continuation of the so far seemingly beneficial conduct of business (Step (n + 1)4a or Step (n + 1)4b). Choosing Step (n + 1)4b is a striking example of human misbehaviour since it implies against better knowledge the risk of running sooner or later into the collapse trap. There is a great number of examples of cases that ended foreseeable in bankruptcy, financial crises and civil wars. The endless and destructive debate about "Brexit" belongs to this list of misbehaviours on the governmental level.

Choosing the release option (Step (n + 1)a) is certainly not free of risks. What is needed is the courage to enter in a rigorous, carefully and professionally conducted reorientation and reorganization phase (Step (n + 1)5) to start a new phase of the adaptive cycle.

5 The Subsidy Trap

In the following the term "human misbehaviour" is understood as acting against better knowledge—knowledge which is well documented in the scientific literature or pretended in law, experience and common sense. We argue that in the case of an outdated economic enterprise—soft-coal mining for instance—providing subsidies is an expression of human misbehaviour with often detrimental long-term effects (e.g. regime shift as illustrated in Fig. 3, and collapse as shown in Fig. 4).

At the entrance of some of the US national parks visitors are prompted not to feed wild animals. "Don´t feed the chipmunks" is written on information boards. With reference to economic systems this slogan could readily be translated to: Don´t support outdated economic systems with subsidies. The animals in the national parks might get used to get food from visitors (comparable to subsidies), get lazy and lose their natural habit to take precautions for winter times. Learning from nature is a good idea, whatsoever, also for managers of companies and State authorities. Investment in innovation, education and transformation beats conservation of outdated business.

Granting subsidies is a typical but often short-sighted counteraction to regain control over outdated unstable sectors of economic systems. Subsidies are granted by governments driven by arguments brought forward by the clientele of lobbyists. They forecast, for instance, increase in unemployment or bankruptcy unless financial aid is granted by state governance. It is known by experience, however, that access to subsidies very likely hampers the readiness of the recipients to strive toward alternative business opportunities, innovative methodology and generation of alternative jobs. Subsidies easily support laziness of the economic actors. Nota bene: State authorities have the responsibility to create the sustainable infrastructural background for ecologically healthy economics. Granting subsidies helps under certain circumstanced but this instruments need to be applied with care and far-sightedness.

Generally, economics, like any other discipline, should not be further developed only as an end unto itself, but as a response to national and international challenges. Solutions to important tasks come not from providing subsidies but from providing wisdom and competences in responsibility. Climate Change and the subsequent meteorological threats—for instance, long-lasting droughts even in areas known as rich in rainfall events - are striking examples of the shortcomings and the insufficient progress in mainstream economics. Required is the development of a widespread understanding that economic growth depends on the preservation of resilience at large, and on functioning ecological systems over the long term.

6 Resilience Thinking: Fundamental of Sustainable Development

Sustainable development is to be understood as a process of change in favour of the long-lasting well-being of society, economy and ecology alike. The definition already points to the fundamentals of resilience thinking which reads: "resilience thinking is a concept dedicated to the achievement and maintenance of the ability of a system to absorb disturbances while retaining its basic function and structure" (see above). In this process, utilization of resources, financial investments, implementation of innovative technologies and governance must be kept in harmony with the basic requirements of the functioning of the local and the global ecology and human societies. The process anchors the security of life on Earth and must therefore be focused on the functioning of marine as well as terrestrial ecosystems. The self-organizational capacity of ecosystems must be confirmed. Humans are subordinated to the primacy of the ecosystem—the intrinsic responsibility of humankind for the whole must be understood as the uppermost goal of the Anthropocene [9].

The "whole" consists of the three interlinked subsystems: society, economy and ecosystems, forming a triad—in our context a "sustainability triad". The term "triad" is used in numerous scientific disciplines to explore and describe the relationships between the three subsystems—also named "monads". In the interpersonal realm, such relationships are often conflictual. Triadic relationships have been particularly researched in psychology. A conflict-free triadic relationship arises from mutual empathy (empathy with others), introspection (perception of one's own inside) and the ability to look to the partners of concern from outside (perception from an external, quasi-objective point of view (Lothar Katz cited by [5]). This creates a paradoxical unity of identity and difference, three are one and yet different".

The three rings shown in Fig. 5 represent the three pillars of sustainability, namely ecology, economy and society, their governmental organization included. Each of these pillars (subsystems) is affected by classes of state variables. Examples are listed in Fig. 5. To maintain sustainable development it is crucial to keep the subsystems of

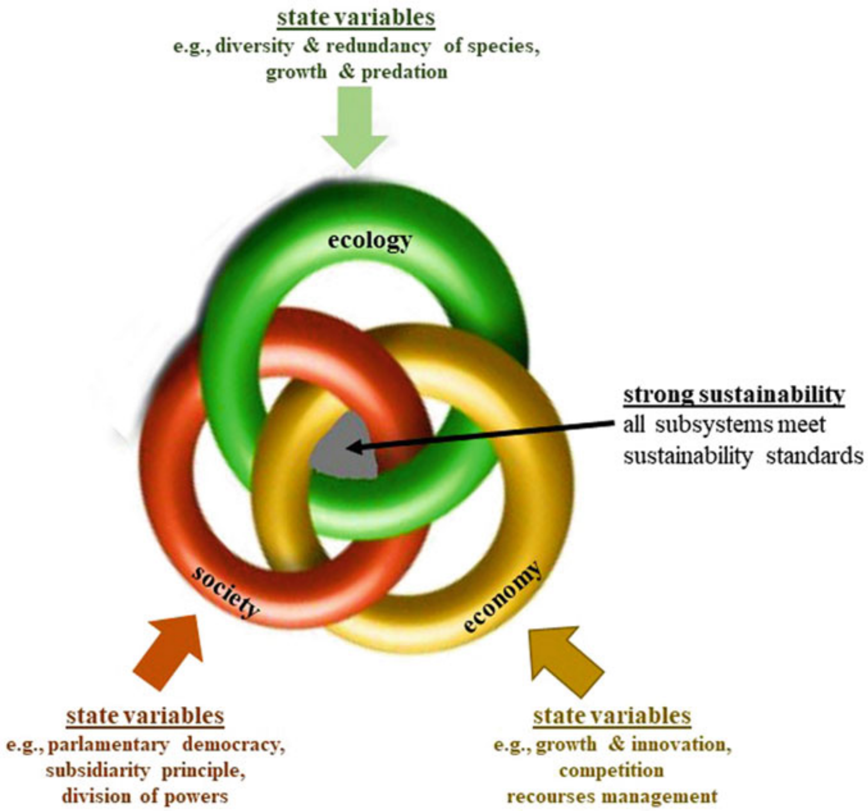

Fig. 5 Visualization of the sustainability triad affected by examples of classes of state variables

the triad as well as the triad as a whole in a state of resilience. Consequently, the interconnection between sustainable development and resilience has been increasingly discussed in the literature (e.g. [3]).

As already mentioned above, diversity and redundancy of species are the most important state variables governing the stability of ecosystems—or in other words the resilience of ecosystems. A high level of diversity allows the system to respond proactively to the variation of external factors like Climate Change. Redundancy describes additional functions to increase the system´s resilience. In case one important species get eliminated another species is ready to fill the niche.

As illustrated in Fig. 4, growth is one of the drivers to keep an anthropogenic system revolving. In ecological systems, predators are important to keep the size of certain species limited and in balance with the locally available resources. Thus, human intervention in the form of hunting or spraying pesticides to control excess growth for unwanted species is an expression of human´s pure understanding of ecological control mechanisms.

Likewise, human intervention in economic systems to respond to changing state variables needs a comprehensive understanding of causes and long-term effects. As shown in Fig. 4, growth is an important kick that triggers the development of any entrepreneurial system. Continuous revolving of an economic system requires awareness of innovative developments inside and outside of the company´s environment as well as careful observation of the changing availability of resources and of the activities of the competitors. Also here, redundancy aspects come into play, for instance, by filling the niche once a competitor vanishes from the scene.

In contrast to ecosystems, problems arise, for example, when growth is accompanied with greed for profits at the expense of resources. Certainly, a company cannot exist without making financial profits. Here, however, we talk about profit generation from products of a limited life expectancy, for instance, fashion wear (clothing, shoes, kitchen appliances, etc.). By aggressive advertisement, customers are forced to buy products, which may correspond with seasonal trends but can get outdated and wasted within months.

In some regions of Europe, the death of a person is circumscribed by "he or she put the spoon away". This saying dates back to the time when especially poor people owned lifelong just one spoon for eating. When passing away this spoon was given to one of the most beloved family members for further lifelong usage. Translated into modern times, it is absurd to consider passing our tape or CD recorder over to our grandchildren when nowadays music comes no longer from any recorder but is streamed by Spotify. And what comes next? And what should we do with the piles of CDs other than throwing them away? In essence, sustainability starts with environmentally sound production, consumption and responsible advertisement.

The third ring in Fig. 5 deals with societal issues. We just pick one aspect, governance. Referring to Fig. 1 the resilience of a societal system depends on the freedom, which the government provides to people, the economy and the remaining close-to-nature areas governed by ecological principles. Likewise to ecology and economy the societal system gains resilience through diversity of its components, and by respecting geographical particularities. It appears, that the parliamentary democracy compared with other forms of state governance offers a solid basis for sustainable development provided the subsidiarity principle is given priority over central governance.

As mentioned above, ecosystems are self-controlled in response to the conditions given in specific areas. A unified control on the global level would not function. Likewise, problems arising on the local scale can be best understood and solved by local authorities. This type of diversion of governmental responsibility is called the subsidiarity principle. This principle is an integral part of the Treaty on the European Union. Some interventions of the European Commission, however, violated this concept and were criticized by the member states and moreover by local people affected by unappropriated regulations. Division of Powers is a further important control mechanism. It provides the basis of stability in a world of rapid changes of challenges and opportunities, and it is the basis of sustainability as it remains embedded in the entire triad.

The seven postulates which are resolved at an IESP workshop held in 2003 in the premises of Kloster Banz summarized by Wilderer et al. [10] are still noteworthy, ready to be considered nowadays:

Sustainability cannot be achieved without eradication of poverty, and poverty eradication cannot be achieved without education. Poverty includes spiritual as well as economic poverty.

Measuring economic activity and quality of life with appropriate indices is necessary. Economic objectives must be balanced with sustainable ambitions.

Education must be based on indigenous cultural knowledge, implemented by local human resources and adapted to local present and future needs. A principal task of education is to develop sensitivity for the gift of life and the natural resources in the heads and hearts of people.

Culture includes religious endeavours. The principles and values common to many religions—such as thankfulness for all goods on which humans depend, sensitivity for all living beings, compassion, humility and solidarity—should be utilized in the formation of concepts of sustainable development.

Economic globalization must be based on local economic activities. Indigenous knowledge about the material and spiritual value of natural resources must be taken into consideration and adequately rewarded.

Sustainable development requires that local societies and economies have adaptive capacity. Local participation in planning and decision-making is necessary to develop adaptive capacity. To strengthen the adaptive capacity of the various societies and economies of the world, participation methods should be further developed and rigorously implemented.

Science and technology are to be understood as an important means to sustainable development. However, technological transfer and technological innovation must be integrated into the local cultural knowledge.

7 Towards a New Enlightenment

Sustainability encompasses widespread responsible utilization of material and immaterial resources. The latter category includes services and rights, education and health, ethical values and arts. Over-extraction of resources as well as pollution of soil, water and atmosphere counteract efforts to establish a world that provides reasonable conditions for a healthy environment, for a healthy human life, and for a functional economy and society. As mentioned in the introduction, Ernst Ulrich von Weizsäcker and Anders Wijkman (2018) propose a new Enlightenment focused on a change of humanity´s behaviour disrupting our common home, the Earth. In other words we may assume, they propose an enlightenment which is based on the concept of resilience thinking, and which globally transforms anthropogenic activities in favour of the continuation of life on Earth.

The former Enlightenment, also known as the Age of Reason, was driven mostly by philosophers and a multitude of intellectuals. It culminated in the eighteenth century and lasted until the beginning of the nineteenth century. The movement was not ordered by anybody but developed by virtue of intrinsic intelligence. The ideas and concepts brought forward were massively directed against the authority of the absolute monarchies in Europe and against the dogmas of the Catholic Church, set as the primary source of knowledge. The scientific methodology of today was formulated at that time as a cornerstone of technology development and industrialization. Over-exploitation of natural resources and environmental pollution which we are suffering nowadays were and are the negative effects of the first enlightenment.

Initiatives for a new enlightenment can hardly be ordered. Similar to the first enlightenment it is to be understood as a process with uncertain results. Could it be that the new enlightenment is already in progress? Some observations support this assumption:

Mobility:

A certain fraction of the young generation favours functionality over possession of goods. For instance, getting comfortably and in time from A to B does not require owning a car or an e-scooter. The alternative services are nowadays provided by companies such as Uber or by car-sharing enterprises. In essence, this type of behaviour contributes to a decrease in the utilization of fossil resources for manufacturing instruments for mobility.

Communication:

Instead of writing a letter, chat services are faster and do not require elaborate handwritten letters. Using icons expresses warm wishes or respectful answers reasonably well. It appears that writing gets gradually outdated.

Global warming:

Through the "Fridays for Future" demonstrations, the young generation stands up, worldwide, to protest against the hesitation of the established leaders of economic and political institutions to take action. As mentioned above, discussions and postponement of the implementation of changes do not save our concurrent vital problem. The young generation, fed of reluctance, insists on taking action before it is too late.

These tree observations might be an indication for new thinking which goes beyond movements initiated, for instance, by Descartes's statement "*cogito ergo sum*". It might indicate the beginning of a new enlightenment based on resilience thinking and the essence of sustainability.

8 Summary and Conclusions

Over billions of years, nature, more precisely self-organized ecosystems, demonstrated the power inherited in life itself. In contrast, the anthropogenic system since not being self-organized needs knowledge-controlled efforts. To be effective, these must be kept free of emotions and free of greed.

The concept of resilience thinking offers a number of mechanisms, which can assist the process of system control. The adaptive cycle is considered the most powerful instrument of resilience thinking in economic entities. Those being in charge of the respective subsystem are advised to keep a close eye on developments outside and inside of the system´s limits, and react to challenges and opportunities with the courage of release from outdated business, reorientation, reorganization and the readiness to start proper activities all over again.

Keeping the anthropogenic systems revolving is only one of the aims to maintain the system's resilience, however. As important is the task to keep each of the three subsystems, namely societies and economies, but also ecologies on the local and on the global scale simultaneously in the state of sustainability.

Sustainability must not be narrowed to conservation. It is a process of change in response to entire classes of state variables affecting the performance of each of the subsystems. Sustainable development requires monitoring of changes and the courage to react timely and appropriately.

Nourishing and expanding knowledge is one of the most important tasks of the "New Enlightenment", provided the "new" conforms to the principles of resilience and sustainability.

A new Enlightenment cannot be ordered by any authority, it must evolve by itself. Recent development suggests that the process towards a new enlightenment is already in progress. This, in fact, raises hope for our common future.

Appendix

On March 28 to 30, 2012, a group of 47 scientists, representatives from regulatory agencies, NGOs, businesses and from media assembled in Wildbad-Kreuth, Germany, to explore whether and to what extent the resilience theory is applicable to sustainable development in general and in particular to finding solutions to tackle global warming, resource limitation, loss of biodiversity and human well-being.

The workshop was entitled: "Resilience as Requirement for Sustainable Development. A contribution to tackle the Earth crises". It was organized and conducted by the International Expert group on Earth System Preservation (IESP), an institution of the European Academy of Sciences and Arts (EASA).

In the following, the messages compiled and resolved by the participants of the workshop[1] are presented.

[1] Friedrich Barth, Werner Bauer, Dr. Franz Bischof, Dr. Josef Bugl, Elena Davydova, Dr. Patrick Dewilde. Dr. Timi Ecimovic, Dr. Helmut Fluhrer, Dr. Jürgen Geist, Dr.-Ing. Martin Grambow, Dr. Hartmut Grassl, Dr. Wolfgang Haber, Dr. Slav Hermanowicz, Dr. Jörg Imberger, Dr. Tara Chandra Kandpal, Dr. Claudia Klüppelberg, Dr. Amitabh Kundu, Dr. Eva Lang, Dr. Anton Lerf, Dr. Tobias Luthe, Dr. Anastassia M. Makarieva, Dr. Franz Mauelshagen, Dr. Hamish McGowan, Dr. Chin Man Mok, Dr. Ulrike Potzel, Dr. Armin Reller, Dr. Axel Schaffer, Helga Schubert, Dr. Yong Hui Song, Dr. Rao Surampalli, Dr. Orhan Uslu, Tom Vereijken, Dr. Norbert Vogt, Dr. Michael von Hauff, Dr. Gisela Wachinger, Dr. Raoul Weiler, Dr. Peter A. Wilderer.

Climate Change and energy demand

The combustion of fossil fuels during the industrial era has become a major disturbance of the global environment—unprecedented in human history. It contributed significantly to the observed unfavourable changes in climate and ecosystems that are currently occurring on a global scale.

Existing energy regimes of industrialized and even more in developing countries are unsustainable and must be transformed. Without a clear pathway to sustainable energy regimes, the Millennium Development Goals are obviously in conflict with targets to reduce GHG emissions. As long as economic growth is dependent on greater amounts of energy consumption based on fossil fuels, sustainable development cannot effectively proceed. The resilience of the climate system is greatly related to human populations, their numbers and their consumer lifestyles. While it is desirable that wealth will be shared more equally among developed and developing countries in the future, it is unlikely that this goal can be achieved in a sustainable way as long as economic growth is considered the key to development, and greater wealth the key to stop the growth of human populations. Energy regimes need to be transformed in the first instance and carbon emissions must be reversed to remove excess carbon from the atmosphere.

It is crucial for industrialized countries to better understand their vulnerability as well as the adaptability of complex social structures and networks to Climate Change in order to be able to make robust decisions towards self-protection. For the greatest part of history on Earth, *Homo sapiens* have lived in small groups and adapted culturally to Climate Change. Its cultural capacity to create new ecologic niches has enabled spread of all landmasses on the globe. Human adaptability created a great variety of cultures making humankind as a whole extremely resilient to changes in the global ecosystem. Today, as a global society emerges, mass extinction of species is paralleled by a loss of cultural diversity. This raises serious concerns about the human capacity to adapt to global change in the future.

Water and food

Water and food supply systems have a unique role since they are vital for human survival and for societal developments. Unlike other commodities, water and food have no substitutes although food sources and supplies are much more varied than those of water. Water and food, including fertile, unpolluted soil, can be considered common goods that benefit whole humanity. The productivity of these systems must be protected. Value of water and food must be fully and appropriately reflected in the economic systems (tiered pricing—"some for free or at low cost, pay for more"). Currently, water and food values are biased worldwide by direct and indirect subsidies. Full accounting (but not necessarily full-cost pricing) of water and food that includes externalities (such as pollution) would provide more socially resilient systems of production, distribution and consumption. This issue may be especially important in the growing energy-water-food nexus. Biofuel production competes for water and land with direct human needs and biofuels are often supported by their own subsidies. If not managed properly, expansion of biofuel production may decrease the resilience of the water and food system because they are pushed toward monoculture plantations.

Water supply and sanitation systems are typically local in scale with a few regional examples (California, Australia). In contrast, food supply systems vary from extremely localized (farming for individual needs) to completely globalized complex networks. Thus, it is likely that resilience enhancement may take different forms for water and food. Multi-scale systems are likely to be more resilient and can be applied to the water and food sector (e.g. distributed water reclamation versus large-scale centralized treatment, small urban garden farming versus agro-business) although the range of scalable solutions will be smaller for water supply than for food. Redundancy and lower extraction ratios (ratios of actual use of water or actual food consumed to their respective maximum potential availabilities) should be beneficial for resiliency although these approaches may make systems less efficient with respect to energy and other resources but less fragile, presumably.

Oceans play a special role in water and food systems. They are not only the source of fresh water in the hydrologic cycle and climate regulator but also a final receptacle for pollutants (e.g. plastic garbage, nutrients, pesticides, sediments, radionuclides). Thus, degraded ocean environments indicate possibly even more severe problems on land. Many people feel emotional attraction to the oceans and the slogan "Do not trash the ocean" might resonate well as a focal point of an awareness-raising campaign.

Ecosystems

Sizeable natural ecosystems are needed as reference points to study the sensitivity of ecosystems with respect to anthropogenic influences and impacts. Human intervention has resulted, mainly due to a long agricultural and forest tradition, in a worldwide disturbance of the functioning of natural aquatic and terrestrial ecosystems. On a major part of the Earth's surface, natural ecosystems have been replaced by artificial biological systems to provide food and biomass to human society. Such systems lack resilience that is inherent to natural ecosystems; by human intervention, they can be maintained in a short-term quasi-resilient state only. At the same time, there still remain vast ecosystems on Earth, including boreal and tropical forests and some regions of the open ocean, that, while disturbed by humans to a varying degree, still operate in the natural regime, retain much of their integrity and resilience and continue to provide particular regional and global environmental services, including the regulation of the terrestrial water cycle. Disruption of these last frontiers of resilience by uninformed human intervention is dangerous but a common practice. Modern clear-cutting of boreal forests in Eurasia is a striking example of this. Governmental institutions are called upon to exercise responsibility for the common. Another example is the misinterpretation of the links between biodiversity and resilience. Research has to be undertaken to not only consider the conservation of rare target species but to better integrate ecological functions and to simultaneously consider producers, consumers and reducers as the three principal functional groups of ecosystems.

It is important to make decision-makers as well as the public aware that our contemporary knowledge is by far insufficient to fully replace the auto-regulative capacity of ecosystems by technology. It is beyond human competence to continuously change and adapt ecosystems to changing climatic conditions and anthropogenic land-use strategies, and thus keep ecosystems resilient. Neglecting intrinsic natural auto-regulation services is very likely to lead eventually to destabilization of ecosystems, and with it societies and economies. Ecosystems provide green space for human well-being. Taking responsibility for ecosystems is greatly facilitated by having a personal relationship with nature. We need innovative methods to deliver information about the importance of fully functioning ecosystems to the society (from childhood on) and to let the public participate in protection work.

Society and economy

Contemporary economies are driven by economic growth. Following the growth paradigm, we tend to forget, however, that within the eco-social triad economic activity has no ends in itself but should serve the needs of the society being a part of the ecosystem. Consequently, the economy should be directed to the well-being of people and to the functioning of ecosystems rather than to quantitative growth for the sake of growing. Among others, human well-being relies on educational achievements, health, easy access to freshwater, clean air and healthy food, safe neighbourhood, physical and/or virtual mobility and intact nature.

Transformation from growth to well-being-driven economies requires the ability and willingness of stakeholders to change and adapt. We need a new understanding of economic progress. Key issues include, but are not limited to the distribution of income, knowledge, as well as the successful management of global commons. Uneven distribution of income and wealth and unequal access to resources affect the resilience of the Earth System directly. While instability in the growth dynamics is a major factor affecting ecological sustainability, even stable and high growth rate is no guarantee of guarding resilience. It would be important to identify the region and context-specific factors impinging on this process and plan for interventions at different levels. Demography, resources, economic growth and societal structure should be considered as key drivers, and local, regional and global aspects may be taken to define spatial levels of articulation of concerns and of intervention.

Considerable research is required to better understand the interaction of drivers and levels and of the interdependence among the drivers and levels. It is necessary to identify indicators pertaining to Climate Change vulnerability and resilience of the Earth System, and quantify economic and social changes taking place across countries, including policies and strategies of intervention. The work may be started on a pilot basis for Asian countries, for instance, and may gradually be expanded to other regions.

Priority recommendations

The resilience theory is likely to provide a sound basis of the development of powerful strategies to drive sustainable development. In order to keep the Earth System resilient, efforts must be made to sustain its auto-regulative capacity.

The resilience of societies and their economies should be strengthened in response to global changes through robust decisions.

The triad of sustainability formed by the three major subsystems, nature, society and economy should be considered the dominant expression of the Anthropocene period. Resilience of this triad is considered the most important precondition for sustainable development and its longevity.

To foster the auto-regulative capacity of the triad, it is of crucial importance to strengthen its ability to continuously change and adapt to the ever-changing site-specific ambient conditions. Continuous re-orientation of the triad must replace conservation of the *status quo*.

Since the site-specific conditions, capacities and limits vary, a mix of local, regional and global, centralized and de-centralized approaches towards resilience and, thus, sustainability is to be favoured over approaches focusing on global governance alone.

Existing energy regimes should be transitioned across a variety of energy sources and technologies, adapting energy systems to local circumstances and de-centralizing energy production.

The vulnerability of complex societal systems (urban agglomerations, communication and mobility infrastructures, industrial societies) to Climate Change needs to be better understood. It is insufficient to base vulnerability assessments predominantly on statistics of national GDP per capita.

Resilience of tropical and boreal forests is to be valued not only because of their capacity to sequester carbon, but even more so because of their capacity to regulate the hydrological cycle.

Water, energy, natural resources, agricultural land, forests and wetlands must all be considered, and treated, as vital common goods.

Technology is an important anthropogenic means to support resilience, but technology-based remediation and control systems must be resilient themselves. Rebound effects must be considered when choosing technology as a means to strengthen the resilience of marine and terrestrial systems.

Efforts to maintain the resilience of the eco-social triad must be communicated at the earliest stage of decision making in order to reach a consensus that the proposed development strategies serve the self-interest of the region and its inhabitants and natural environment.

To better understand and manage the complexity of the relevant eco-social systems within our societies, new inter- and transdisciplinary approaches and methods are required. Efforts must be undertaken to extend the knowledge of qualitative and quantitative dynamic network models and analysis of human–environment systems, in order to find leverage points for effective intervention, and transfer such insights into practice.

Urgent research tasks and questions.

How to identify and which are the most effective points of leverage and drivers to alter complex eco-social systems towards higher resilience and sustainable growth?

Taking the world economy as such a main driver, ways to internalize external effects while de-coupling economic growth from resource degradation should be found; thus, developing a functioning world carbon market must be of utmost importance to self-regulate economies.

How do sustainable energy regimes interact with local and regional environments, and how can they be set up in a most resilient manner?

In which way and to what extent are complex social structures and infrastructures in urban areas and industrial structures vulnerable to Climate Change? What are the feedbacks of Climate Change in these structures?

In what way does the loss of cultural diversity, caused by globalization, affect human adaptability to Climate Change and global environmental change in general?

If re-orientation and innovation are accepted as major driving forces of continuous change and adaptation, which methods are to be generated and deployed that provide knowledge-based orientation? Which methods and strategies are to be developed and implemented to optimize a two-way science-society knowledge transfer?

What are appropriate measures to quantify the integrity of local and global water and food supply systems?

How to manage optimal level food supply from oceans, while the resilience of marine systems remains secure?

How to quantify the "value" of natural and human-influenced ecosystems?

How to effectively fit protected ecosystems into human land-use structures? Can the "diversity of land-use concept" serve as a framework to integrate different ecosystem functions on the regional scale? How can global commons effectively be managed at local, regional and global scale?

What exactly is the importance of biodiversity with respect to resilience of anthropogenic ecosystems? What are the links between biodiversity, the environment and its functions? What role do producers, consumers and reducers play in the context?

Under which conditions are the extinction of native organisms and intrusion of alien organisms into an anthropogenic ecosystem a threat or sign of auto-regulation?

How can an economic system based on growth be transferred into a system serving the well-being of people?

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Is the Global Economy Running a Pyramid Scheme?

Mathis Wackernagel

Abstract We now live in the "Anthropocene". Human dominance of the biosphere is the result of global ecological overshoot, breaching several ecological boundaries. Overusing the future's resources to run the present economy is a clear example of what lawyers and economists call a "pyramid scheme". Such a scheme is highly unstable and self-destructive, and therefore outlawed in most countries. How come, though, it is tolerated in the ecological domain? Why is our current ecological overshoot not even generally acknowledged as a pyramid scheme? Can it even be seen if the physical dimension of human existence is largely missing in policy-oriented sciences? Why is it missing in current social sciences? Through these questions, this paper explores what might be key reasons behind our societies' inability to respond to this massive pyramid scheme. It proposes that unacknowledged and undigested colonial philosophies are still deeply embedded in those sciences. These hidden philosophies may be key contributions to our dangerous blindness and our distorted collective situational awareness.

Keywords Global economics; Pyramid/Ponzi scheme · Climate change · Colonial past · Social theory

1 Introduction

The answer to the question raised in the title of this chapter is straightforward: Yes. It is hard to imagine a more obvious case of a pyramid scheme (***see*** **Box 1**). Humanity's resource overuse is clearly robbing the future to pay for the present. It requires constant depletion of our underlying natural wealth to maintain the current income. Ultimately, if not rectified, this ends in ecologically bankrupting humanity.

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Therefore, pyramid schemes in any form are illegal in most countries.

How come then, we let the ecological pyramid scheme run amok collectively? Let me first outline how big this ecological pyramid scheme is, before speculating about possible reasons we have not been intervening. Then I will identify possible pathways to rectify this challenge.

BOX 1: What is an Ecological Pyramid Scheme?

Pyramid schemes ("Schneeball-System" in German) are a scam in which you rob Peter to pay Paul. Unfairly, they are often attributed to Charles Ponzi. It's possibly another gender bias in history, because fraudsters Sarah Howe in the US and Adele Spitzeder in Germany predated Ponzi by at least 40 years. The former swindled Boston ladies [21], the latter ran a bank that defrauded over 30,000 people and led to a loss currently valued at 400 million Euros [8]. There are good reasons to believe that others figured out pyramid schemes even before these two ladies.

No one has been greater at implementing pyramid schemes (called Ponzi schemes in the US) than Bernie Madoff, whose version involved $65 billion of client money. His strategy, like his predecessors, consisted of relying on a steady flow of new investments to provide "returns" to earlier investors. He took from the future to pay for the present.

Yet collectively, Madoff has been massively outdone: Our current economies are running the largest pyramid scheme ever. We are depleting the Earth's future biological resources to run present activities. Currently, humanity consumes the planet's biological resources more quickly than Earth can replenish them. Whether financial or ecological, debt balloons eventually burst. Humanity's ecological debt shows up as excessive carbon in the atmosphere, collapsing fish stocks, shrinking forests, eroding soils, and ground-water drying up.

Pyramid schemes are bound to come to an end; the question is whether by design or disaster. It is more rational to prefer design, but it requires honest accounting and resolve.

2 The Scale of the Pyramid Scheme

This is the situation as I see it: Colossal overuse of Earth's natural capital leading to the climate crisis and biological mass extinction have made the protection of the biosphere the top priority for securing human and non-human life on our planet. Hence, the speed and scale of the needed transformation is large, even if we assume that Climate Change is the only issue in need to be resolved—but it isn't [2]. The Paris Climate Agreement gives us guidance in this pressing issue: it commits humanity to never warm the planet to more than 2 °C beyond the pre-industrial global average temperature (and if possible only 1.5 °C) [26].

This temperature limit translates into a clear upper greenhouse gas threshold: According to the fifth assessment of the IPCC, an atmospheric greenhouse gas concentration of 450 ppm CO_{2eq} (meaning CO_2 equivalent, which includes all relevant greenhouse gases) would give humanity a 66% chance to stay within a 2 °C global warming limit [15]. This is an upper threshold, because a 66% chance of not exceeding 2 °C is far weaker than "holding the increase in the global average temperature to well below 2 °C" as stated in the Paris Agreement. Yet NOAA, a science agency of the US government focused on the conditions of oceans and the atmosphere, reports that in 2020, the atmosphere had already reached 504 ppm CO_{2eq} [4]. The latter number being massively higher than the former suggests that there is no carbon budget left any longer. Living up to the Paris Agreement would therefore require a very rapid decarbonization. This means ceasing fossil fuel use, producing cement without carbon emission, plus pushing forward large amounts of carbon sequestration, all well before 2050.

Whether humanity decarbonizes proactively, or eventually runs out of exploitable fossil fuels (leaving a massive greenhouse gas debt in the atmosphere), humanity will inevitably have to live off our planet's regeneration, not its liquidation. The earlier humanity can transform, the more our planet's regeneration capacity will be left. In other words, the swifter humanity curbs its fossil fuel demand, the more of the planet's regenerative resource budget will be safeguarded. Decarbonization requires focus and willpower, since other energy sources take more effort. After all, the versatile and powerful fossil fuels have massively eased people's biological budget constraints during this era.

Fossil fuel helps to produce far more food and feed thanks to fertilizers, pumps and tractors; it also enables storing, processing and shipping of food and feed around the world, overcoming local food production limitations. It substitutes many biological fibres, with 70% of fibres now produced synthetically [1]. Additionally, it heats more houses without burning wood, and it gets people around the world without feeding horses and donkeys.

This fossil fuel use has amplified human demand to an extent where it now exceeds what the planet can renew. Global Footprint Network's estimates, possibly the most comprehensive ones available worldwide, indicate that humanity demands at least 73% more from our planet than its ecosystems can renew [17], Global Footprint Network [10],). This is like using 1.73 planet Earths.[1] But to safeguard 85% of the world's biodiversity, humanity would need to use less than half of the Earth, according to E.O. Wilson [33]. Consequently, human demand has grown to over threefold (or 1.73/0.5) the rate that could be compatible with lasting conservation, including stabilizing our climate.

[1] This result is for 2017. Estimates for the first half of 2020 indicate that the COVID induced lockdowns reduced humanity's demand on nature about 9 % compared to 2019 [11], at least in the first half of 2020 [18]. Estimates for 2021 suggest that the level of overshoot rose again to the same level as 2019 [18].

This 3-factor gap, accelerated by the pyramid scheme, merely represents an average. It does not reflect that many members of humanity still need more materials and resources to thrive. The current resource gap also does not reveal that the average human family keeps growing.

Further, protecting nature is, in itself, an important goal. Nature's aesthetic and spiritual value is unfathomable. Yet, the goal to protect sometimes clashes with people's ambitions and material demands. These demands have become so big that protecting nature has become even more urgent if humanity wants a future where all can thrive within the means of our planet.

What may be underappreciated is that it is possible for human demand to exceed planetary regeneration for a while, because there are stocks that can be depleted; it is even possible to increase demand during such ecological overshoot. Still, because of basic laws of physics, eventually demand will be reduced again to the planet's (potentially diminished) regenerative capacity—the question is only whether humanity will get there by design or disaster.

The urgency is growing because the massive technological progress witnessed over the past 100 years has amplified, rather than decoupled, human dependence on the biosphere. This situation is not easy to shift since despite astonishing cultural and technical accomplishments: humanity remains ill-equipped to resolve the ecological sustainability challenge, including biodiversity preservation. As a result, pressures on the biosphere are increasingly threatening humanity's achievements—and the future of all other species.

3 Is There Merely One Key Factor Limiting Human Response?

To solve this complex challenge, a sharp understanding of its cause is required. Certainly, there may not just be one cause. In fact, it is easy to brainstorm a long list of potential reasons driving this problem.[2] But that's not actionable.

The science community still lacks a sharp understanding of the mechanisms that hold humanity back from addressing the pyramid scheme leading to Climate Change and resource constraints. Given what is at stake, this may be humanity's most significant knowledge gap. Without this knowledge, it will be unlikely that this pyramid

[2] There are always many contributing elements shaping a problem. For instance, with COVID, one could identify an r-factor higher than 1 as the central reason for the spread of the corona virus. There are multiple things that determine that one reason (the r-factor). In the COVID case it would be vaccination rates, number of social interactions, proximity of people and ventilation, face protection, susceptibility etc. Each one of them contributes to the r-factor. Still the r-factor can be seen as the single determinant of the outcome. Therefore, we could formulate the question as: What is the "r-factor"-equivalent enabling the ecological pyramid scheme?

scheme can be stopped deliberately and with minimal pain before the scheme unravels itself brutally and uncontrollably.

This section makes the case that more effort needs to be put into identifying the most influential causes that keep us from dismantling the pyramid scheme, starting by developing some hypotheses.

Certainly, the pyramid dynamics have a lot to do with two underlying forces identified by Nate Hagens [12]. The first factor is efficient fossil fuel access (meaning it has a high energy return on energy investment). This first factor gets accelerated by the second one: the availability of financial debt enabling investments in industrial technologies that can extract and use ever more fossil fuel. These two forces keep expanding the pyramid scheme. Given the large amount of fossil fuel stocks in the Earth's crust, the scheme has persisted for nearly two centuries with large-scale effects like Climate Change becoming increasingly visible.

Could it be one single reason for humanity not taking this risk seriously? Or is it a necessary confluence of several ones, possibly with one "last straw that breaks the camel's back". For instance, modern-day flight procedures are designed in a way to make sure that planes are always half a dozen errors away from crashing. This means crashes only happen if a combination of errors occurs simultaneously. Multiple errors happening at the same time is by magnitudes less likely than any single error cropping up. Therefore, the airline industry carefully keeps track of all errors: It is error-positive, encouraging all operators to report any error they have encountered or caused. This knowledge gathering about all possible errors then leads to decreasing the likelihood of all errors, with the consequence of fantastically low airliner crash rates.

Still, some errors or occurrences are more significant than others. Understanding such limiting factors opens up more effective intervention opportunities, as advocated by Buckminster Fuller through his the promotion of "trim-tab solutions". Inspiration for the possibility of such key drivers comes from the agricultural sciences: "Liebig's law of the minimum". German chemist Justus von Liebig popularized the notion that plants require various inputs to grow (water, sun, phosphorous, nitrogen, CO_2, etc.), but the one in least supply limits the overall growth of the plant. For instance, if a plant has sufficient water, but is limited by nitrogen, providing the plant with more water will not increase growth. The question is whether a similar dynamic may also be true for human systems, where one (or at least very few) particular issues limit improving the situation.

Therefore, efforts to search more deeply for underlying reasons that influence a complex behaviour like the current pyramid scheme may be needed to design meaningful, impactful responses. This contrasts with the current discourse in the sustainability arena which is filled with presumed solutions, but are lacking in clearly defining the problems. The proliferation of such approaches may be stimulated by unclear or diverging sustainability definitions. They may thereby hinder rather than accelerate the transformation.

For fear of being labelled a reductionist, I do acknowledge that complex human dynamics may not be determined by one single driver. Such dynamics are best described as interlocking systems with multiple feedback loops. For every driver of such a dynamic system, it is always possible to find further causes behind each driver. These causes may be part of causal loops, rather than leading to a "root cause" in a linear chain of events. Nevertheless, systems analysts have shown that it is possible to identify those elements that have a particularly large influence on the overall dynamics of the system (see, for instance, Frederic Vester's "Papiercomputer," [28].

To initiate a more systemic analysis of the question, the following section identifies potential key drivers behind this challenge. This is continued speculation in search of useful hypotheses.

4 Possible Key Drivers for People's Underwhelming Reaction to the Pyramid Scheme

This is how I see the challenges, based on experiencing the field over the past few decades:

- I do not view the limiting factor for tackling our planet's ecological crisis to be a *lack of scientific research* documenting the physical manifestations of these trends (yet, the importance of such research is undeniable).
- It is not a *lack of enlightenment.* We have never had more elaborate and large universities around the world, and never have the number of graduates been higher.
- Nor are we *lacking acknowledgement in political debates* that these trends are happening and this acknowledgement needs to be broadened.
- *Nor is it the biological setup of the human brain.* The human brain does show weakness in thinking systemically and deductively, and gets easily overpowered by inductive stories and emotional shortcuts as discussed by many, including [12].[3] But then, there have been uncountable researchers describing the problem, i.e. their brains were able to recognize it. Also, there have been many areas of human endeavour that have been able to address abstract collective challenges. Examples include legal systems, educational institutions, insurance, public health efforts, aviation regulations, etc.

In my view, the most crippling bottleneck is the *insufficient recognition that reacting to this pyramid scheme is also becoming an economic necessity* for each country, city or company, particularly to protect themselves (and much of this reaction will also co-benefit and protect the global commons).

Most countries, cities or companies still ignore that they have profound "skin in the game"—that their well-being and success depends on taking their ecological context seriously. I know of only a few competitive, national development or corporate business strategies, which recognize the global ecological context as a significant parameter of their own success.

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[3] In the same vein, MIT scholars Vosoughi et al. [29] demonstrated that our inductive brains respond more pro-actively to catchy stories, amplifying the spread of "fake news". Their "research project finds humans, not bots, are primarily responsible for spread of misleading information." [7].

The underlying reason may be that social sciences, such as economics and political science, are largely devoid of physical considerations, such as space and matter, but also to a lesser extent, time. Obviously, these academic disciplines are not totally devoid of physics. History recognizes time. Economic analyses include interest rates or discount rates, which are a response to the reality of time. Some economic disciplines specialize on physical aspects of reality, such as environmental economics or agricultural economics. But none of these sub-disciplines of economics recognizes physical constraints to economies, not even the ones imposed by a finite planet: They do not answer whether there is an optimal scale of the physical size of an economy compared to the size of the biosphere. Development economics textbooks sometimes do mention physical conditions, but mostly, they cast resources as a disadvantage to national economies [5, 16, 9, 22, 23]. They emphasize the "resource curse," a view that portrays the availability of large resource stocks as harmful to countries since they may encourage corruption and distort the market through rent-seeking activities.

Even other social sciences, from sociology to conflict research, underestimate the physical context of society. Sociologist William Catton wrote a unique book about the implications of ecological overshoot (1980), with to my knowledge, barely any other sociological studies before and after acknowledging the physical context of our planet as a central theme for societies. Conflict studies are also unclear about the role of natural resource availability in generating conflict. For example, Henrik Urdal, head of the Peace Research Institute of Oslo, stated in a recent *Washington Post* article that there "isn't scientific consensus that there is a linear relationship between Climate Change—or resource scarcity, more broadly—and armed conflict" (2019). This statement surprises me, given the history of colonialism, or given the enablers of today's migrations (e.g. from resource-scarce Central America to the US, or from resource scarce, economically challenged, and often conflict-ridden Middle East and Africa to Europe).

Another example demonstrating the physical blindness of conventional macroeconomic policy thinking is presented every year in Davos to world business and policy leaders: The World Economic Forum's Competitiveness Report [30]. It claims to assess country competitiveness while omitting resource or environmental considerations. Not one of the 103 indicators making up the competitiveness score (the long-term ability of countries to generate economic wealth) measures aspects of resources or the environment. This is even more startling considering that the World Economic Forum's Global Risks Reports, based on the opinion of over 1000 CEOs, conclude that 9 out of the top 10 current global risks are resource-based or environmental ([31]: in 2019 it was 7 out of 10, in 2018 6 out of 10). Since avoiding dangerous Climate Change implies full decarbonization within a couple of decades, it seems that even a short-term interpretation of competitiveness—i.e. an economy's future ability to produce value-add—would have significant overlap with the concept of sustainability.

One implication of the lack of physical understanding is people's inability to react to the climate and resource challenges. It leads to an outdated climate narrative, which keeps portraying sustainability as a noble cause, rather than a necessary one. Too few recognize that the efforts towards resource security and climate action are not only thoughtful gifts to humanity, but also essential and urgent drivers to build their own successful future.

5 Why is the Physical Dimension Missing in Policy-Oriented Sciences?

To conclude this paper's tentative exploration into the key reasons behind our inability to respond to the pyramid scheme, let me present even more speculative observations and interpretations—to stimulate further debate about underlying causes.

If it is indeed true, that social sciences informing modern policy lack biophysical understanding, the question arises: why do the social science disciplines exclude readily available knowledge from other disciplines such as physics, biology, engineering and architecture?

Social sciences, particularly economics, have not always been devoid of physics and thermodynamics. Classical economists (including John Stuart Mill or Stanley Jevons, and early economists like William Petty) and even social critics like Karl Marx or Thomas Malthus, had a far more physical interpretation of reality than western economists post-World War II.

My reading is that the horrendous nature of World War II, with the final defeat of Hitler, led to a purely ideology-focused interpretation of that massive war. Historians have given far more attention to competing narratives, and less to underlying causes. Hence, the war has been mostly construed as an ideology (i.e., fascism) gone awry, leading not only to large-scale conquests but also to the organized and systematic genocide of Jews, Romani people, and others, and the aggressive deadly persecution of homosexuals, leftists, and many others.

However, interpretations that focus on colliding ideologies miss out on the war's meta-theme: new colonial ambitions (Japan, Italy and German) clashing with established colonial empires (such as the UK, France, Belgium, the Netherlands, Spain, Portugal), and colonialism being internally and externally challenged. Large-scale colonialism had been in motion since at least the Roman Empire and independently in other parts of the world (Incas in South America or the various Chinese dynasties). The emergence of European powers, post the middle ages, extended those regimes' control over ever larger stretches of Asia, Africa and the Americas, and eventually Oceania. Colonial ambitions amplified on the eve of World War II. For instance, Japan ruled Korea after 1910 and started to conquer and occupy portions of China after 1937, eventually capturing big portions of Asia in the following years. Italy started to overtake Abyssinia in 1935. When Germany, with renewed colonial ambitions, turned into a threat for France and the UK after overrunning Poland, the US was reluctant to intervene initially. One reason was that many US citizens did not want to use US military resources to rescue their former colonial master, the UK. They felt that the UK had to pay its own price for its colonial ambitions.

My colonial interpretation of World War II is not to dismiss the conflict of ideologies. Rather, the point is that ideologies or narratives instigating conflicts are more often means to an end, the end being controlling another territory. No army or country can be motivated to grab others' territory by advocating being robbers. Rather, a heroic story has to be told that legitimizes the intervention, whether it is revenge for past injustice (e.g. the Versailles Treaty), dismissal of others' rights (e.g. claim of ethnic superiority), or neutralization of a threat (e.g. fear of Bolshevism). The Allies had ideologies that celebrated, as part of their heroic narrative, being "defenders of democracy and civilization"', which is clearly preferable to a fascist ideology. But this Allied ideology still covered up the reality that most Allies were also colonial powers, a contradiction that was never officially resolved.

The eventual defeat of the Nazis and Hitler enabled the winning powers, with the US in the lead, to develop the post-war agenda. The western powers (coming together at the 1944 Bretton Woods conference) ignored the colonial dimension of the war, including the demands of many leaders in colonized countries to achieve self-determination (Julius Nyerere, Kwame Nkrumah, Mahatma Gandhi, Jawaharlal Nehru, Haile Selassie, Sukarno, Mao Zedong, Ho Chi Minh and many others). Using the need for post-war reconstruction, the agenda of economic "development" was promoted, facilitated through the Bretton-Woods institutions, and avoided the question of self-determination. The Bretton Woods agenda focused on the development and on international monetary systems revealing a staggering absence of any colonial discussion.

This agenda is still alive today, and essentially endorsed through the UN system. Only by 1960 did the UN (under the abstention of eight colonial powers) recognize countries' right of self-determination, calling for the end of colonialism. The development agenda covered up the reality that colonies had been major natural resource providers for the colonizing countries, and that industrialization of the colonial centres were fuelled with the resources extracted from their colonies.[4]

The current development agenda barely acknowledges the role of resources, mostly covering the topic under the rubric of "global trade" and "economic growth" and arguing mutual benefit, thereby denying the possibility of systemically unfair conditions and exploitation. Further, there is a lack of acknowledgement that market prices do not reflect the true significance of natural capital and labour. Mainstream theoretical approaches ignore, if not favour, the systematic economic advantage of metropolitan areas: they capture large portions of the value-add in every value chain. They achieve this by controlling brands, IP rights and distribution (e.g. "made in Switzerland") [32].

[4] In contrast, some argued during the height of Europe's colonial extension, having subjugated 84% of the globe [13], that financially the colonial ventures were not net-positive for the colonizing powers [3]. They implied that colonial powers subsidized, rather than exploited, their colonies. In reality, it is difficult to believe that colonies were merely held as a generous civilization project of the colonial powers in favour of those being colonialized. Such financial claims also turn a blind eye on the brutalities of colonialism. The fact that colonies were clearly seen as exploitable assets, owned by "mother countries" is demonstrated in news articles of the time, such as those in the [20] in which the benefits of the colony's resource assets are discussed with great candour.

Further, the unhelpful (non-descriptive and non-explanatory) terminology of "developing countries" and "developed countries" is a symptom of this agenda. The terms continue to be widely used even though they have no clear definition. They even seem to legitimize or at least normalize the colonial history. This terminology, introduced post-World War II hand-in-hand with the Bretton Woods institutions, is still omnipresent within the UN system to this very day, including in climate negotiations. This distinction of countries conjures the idea as if there existed only two possible states of operating, and as if Western European/US type economies were the only possible goal, or way to organize countries. Yet, if all people lived like US residents, it would currently take five Earths according to [11],—clearly not a replicable model either.

This emerging development doctrine was tightly linked with the budding neoliberal economic theory, which dominated the economics departments of influential universities, particularly in the US. It was the most prominent and influential economic theory from World War II onwards.[5] In essence, the colonial past, with all its injustices, resentments and guilt, was never recognized, reconciled, nor reflected upon, certainly not within the Bretton Woods context. Even during the time of decolonialization after World War II, there was, among the colonial powers, no mainstream debate questioning the legitimacy of past (or ongoing) colonialism. Nor was there any effort to revisit that past, seek understanding, or even reconciliation. Rather, the emerging development doctrine provided by the Bretton Woods institutions (and the emerging international development agencies of OECD countries) offered an alternative interpretation that accommodated this blind spot. As a result, at least within OECD countries, there was little intellectual wrestling with the legacy of the colonial past. This contrasts with the "truth and reconciliation" approach initiated by Nelson Mandela for South Africa, which was an innovative and powerful attempt to revisit and overcome the wounds of apartheid, possibly the reason for avoiding a potential civil war. Nothing even remotely like that has ever been considered by governments of countries with a colonizer past.

The following example serves as an additional piece of evidence for how profoundly the colonial past has been ignored: a lengthy, documented conversation between two influential European progressives, the French ex-president Mitterrand and Eli Wiesel [19]. While they discussed in detail the horrors of World War II for the French and their home territory as well as the atrocities of the holocaust, they did not mention or reflect on France's or Europe's colonialism (pre- and post-war), and the millions of lives it cost. This is curious given that during the post-World War II independence struggles, for instance of Algeria and Vietnam, Mitterrand occupied ministerial positions and thorugh those positions fought against independence.

Here I attempted to we identify the absence of recognizing, or even reconciling with, the colonial past as potentially the reason for social sciences ignoring physical reality. This focus on unreconciled colonialism is not to downplay the systematic

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[5] China, in contrast, having been subject to colonial aggression and having been isolated from the Bretton Woods debate for decades has still a far more resource informed economic development doctrine. Its five-year plans are filled with references to resources, environment, energy, or nature.

racism and atrocities of the Nazis. Rather, this acknowledgement helps us to pinpoint why modern economic and social theory emerging in high-income countries underplays the significance of society's physical foundation—ultimately to those countries' own peril. By being complicit in ignoring the wounds of colonialism, modern social theories including economics that lack a physical foundation, are ill-equipped for addressing the resource and climate dimension. More specifically, this active denial of the colonial era and its function to supply the colonial centres with resources, in my view, led to the inability of our modern policy apparatus to productively deal with Climate Change and resource constraints.

The underlying colonialist assumptions, though unspoken, are still accepted operating principles. For instance, resource security is nearly absent from any competitiveness or macro-economic discussion. Also, urban elites continue to assume that it will always be possible to maintain their privileged position of getting sufficient energy and resources from "somewhere else". Both the rapid urbanization trends and the lack of concern among urbanists whether there will be sufficient natural capital to support the expanded urbanization serve as pieces of evidence that such colonial thinking is still prevalent.

This, hence, is what I offer as a **hypothesis**: the physics-devoid modern social theories (including economics, sociology, urbanism and political sciences) are a legacy of an actively ignored and covered-up colonial past. As a consequence, reconciling with, or at least recognizing, that past may be necessary to fully embrace again the physical nature of our individual and collective existence [6]. The benefit of such a reconciliation would be our ability to heal and upgrade economic thinking, so it can deal with the physical challenges our economies are facing. Such upgraded (physically informed) social theories would help us recognize that currently we live off depletion and that sustainability is a necessary ingredient for securing everybody's prosperity.

6 The Benefits of Reconciling with Our Colonial Past

Accepting our physical context will make the climate and resource challenge far more manageable. It would make obvious that to avoid dangerous Climate Change, humanity would need to be out of using fossil fuel well before 2050. If we embraced this reality, every mayor, minister, or CEO would start to ask themselves: How much of our infrastructure for 2050 is already built? How much of it is fit for this transformation? How much of our assets will be stranded? What are the needed action steps to strengthen our position in a world of Climate Change and resource constraints? CEOs might also ask: how will my company be relevant 20 years from now?

Accepting our physical context would make these questions obvious for anybody who is interested in their own personal success.

There is no other possible future for any company, city, country and humanity as a whole than to eventually live off the planet's regeneration, and not its liquidation. Our only choice is how fast we choose to transition away from an ecological pyramid scheme. The earlier humanity transforms, the more regeneration will be left. The earlier humanity curbs its demand, the easier it can fit within the planet's resource budget. Possibly even more importantly: Early adopters will be far better positioned to succeed: they will have their economy and infrastructure (roads, cities and power plants) adjusted in time. After all, it is a question of competitiveness. Others who start early will have a bigger struggle since our physical assets come with enormous inertia and take time to retrofit or replace.

Recognizing the significance of Climate Change and resource constraints for competitiveness means that companies, cities and countries would embrace, in theory and practice, that their own ability to successfully operate their economies hinges on their own ecological performance.

All this leads me to inviting you: What is your hypothesis about why collectively, we people have not been able to react meaningfully to the climate and resource conundrum? And how does your hypothesis contrast, contradict or complement the hypotheses presented here? Let me know, because I am deeply curious.

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Climate-Positive, Sustainable Agriculture Is Possible! Cornerstones for Public-Interest-Agrarian Policies

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Abstract Three central challenges measure and test the sustainability of agriculture: feeding an ever-increasing number of people on the planet, protecting the climate, and preserving biodiversity as well as the natural foundations of life. If the twenty-first century succeeds in coherently shaping these three conflicting aims within our planetary boundaries (Steffen et al. Sci 347(6223), [1]), then basic agricultural production, the first and foremost sector of any economy, will be transformed and ready for future generations. This article suggests that digitalization will be a prime mover towards a sustainable, climate-positive food security and biodiversity conservation that uses the potential of agriculture and forestry as well as horticulture and fisheries to effectively remove CO_2 from the atmosphere. The first step towards this transition, however, must be the closing of regulatory gaps and restructuring of funding schemes.

Keywords Sustainable development · Agriculture · Land use · Biodiversity · Digitalization

1 Introduction

A 2019 Forsa poll of German farmers on the future direction of German and European agricultural policies shows that 44% of farmers questioned would be in favor of receiving more money for environmental and nature protection, and compliance with environmental regulations by 2030, while doing away with the current lump sum subsidies [2]. This proves that large sectors of agriculture support the notion of receiving public funds for public services. For years this has been

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posited in political party programs as well as by broad-based alliances of civil-rights activists working for climate, environmental, and natural protection and representatives from future-oriented agricultural advocacy groups like the Bundesverband deutscher Milchviehhalter (Federal Association of German Dairy Farmers) or the Arbeitsgemeinschaft bäuerlicher Landwirtschaft (Working Group for Rural Agriculture).

This shows that a change in agrarian practices which would save the climate as well as genetic diversity, while simultaneously guaranteeing food security, has been debated in political and economic programs and has the support of many stakeholder groups. And this change is within the range of feasibility. Its main feature is a reorientation towards the common good. It can be understood in terms of sustainability or the Sustainable Development Goals: The guiding principle for the current regulatory framework is an economically resilient, agro-ecologically diverse, and socially acceptable form of agriculture, able to incrementally and noticeably reduce climate impact, with the goal of implementing public-interest agrarian practices all over Germany and Europe by 2030.

2 Climate-Positive Agriculture Works

Meeting the first challenge of climate protection in agriculture, there is justified hope for future decades of setting out on a transformational path. "There are pioneers in several areas of the world that provide well-founded evidence that climate-positive agriculture with high economic value added is possible. The Wies-Hof located at Neuheim in central Switzerland, engages in cattle farming (60 heads of cattle), local fodder cultivation, humus formation, and grows standard-size fruit trees, in addition to the production of biochar and a composting plant. Instead of the usual Swiss emissions of 115 t CO_2-equivalents per farm on average, the Wies farm extracts 380 t CO_2 from the atmosphere every year and is therefore clearly climate-positive. Thus these 13 ha offset the CO_2-emissions of 65 Swiss citizens" [3].

Indeed: This exemplary pioneering enterprise irrefutably proves the transformational potential for the entire agricultural sector. Agriculture, together with forestry and other types of land use, is responsible for approximately one quarter of greenhouse gas emissions. There is nitrous oxide from nitrogen fertilizer, methane emissions from metabolic processes of certain farm animals, CO_2-emissions from fossil fuels and other combustibles from agricultural machinery and farm buildings, emissions from farm fertilizer storage, transport of agricultural basic products (seeds, fodder) as well as emissions due to trucking of agricultural produce (e.g. milk) that are detrimental to the climate.

This list of climatic impacts due to common conventional or industrial practices of the production of raw materials makes the implementation of socially agreed upon global climate goals for agriculture in Germany and large parts of Europe very difficult. However, closing the CO_2-cycle for work in agriculture and forestry is essential for the entire area of climate-neutral economic activities. Farmers' associations like the Deutsche Bauernverband (DBV; German Farmers' Association) recognized this and have developed appropriate climate strategies [4]. However, a successful implementation will depend on regulatory political decisions. Additional regulatory policies will be necessary, and on a more ambitious scale than previously deemed enforceable, to ensure that land management will make a significant contribution to solving the problem of climate protection.

First and foremost, regulatory support measures would have to create a long-term framework enabling agriculture and forestry as well as horticulture and fisheries to increase their potential of effectively removing CO_2 from the atmosphere. Seen globally, trees, plants, algae, and humus formation are capable of capturing climate-relevant amounts of CO_2, provided long-term storage of carbon in soil and in novel organic materials (biochar or building materials) will be possible [5].

There is a variety of agro-ecological practices such as agro-forest systems, symbiotic agriculture, permaculture, mixed fruit cultivation, and organic agriculture as a whole that appear to be favorable in view of their climate impact. As early as 2008, the World Agricultural Report noted that a sufficiently large number of regionally adapted practices are available worldwide, capable of providing enough food for a growing global population [6]. In 2018, the World Future Council together with the FAO showcased many exemplary agro-ecological practices worldwide that are worthy of emulation. Undeniably, there are many opportunities in agriculture, forestry, and fisheries for meeting socially desirable climate-protection goals in primary economies [7]. In case of an ecological renewal of the market economy in the primary production sector, enforcement of what is practically feasible as well as socially desirable for many, coupled with appropriate regulatory measures, would be politic as well as in the interest of the common weal.

Assuming that climate protection represents a priority target of a public-service-oriented sustainable agricultural policy, one future minimum legal requirement would be that all agricultural policy support and protection measures would have to be put to the test as to their climate-positive practices in agriculture and forestry. Only measures promising transformations in the direction of climate neutrality, resp. climate benefits, would be publicly funded. Various studies have shown that investment funds required for a turnaround towards climate-positive agriculture would be economically feasible through a CO_2-price reform and disbursement for agriculture [8]. A commensurate CO_2-price and legally regulated certificate marketing would allow for tradeable emission rights going to individuals in agriculture, thus representing additional income for necessary farm or forestry investments serving climate-protection goals. Given that humus formation sequesters CO_2, an easy marker would be the amount of humus formation by individual agricultural enterprises [5].

The decisive factor is the price per ton CO_2. Currently, calculations for one ton of CO_2 vary between 20 and 180€. It is obvious that only a political decision will resolve these discrepancies. As shown by the EU's emission trading, society as a whole signals agreement of taking climate protection seriously by encouraging politically consensual pricing and climate certificates. A novel way would be the identification and legal enforcement of second-tier mechanisms stipulating what price share of

CO_2-compensation measures from the food processing or service sectors would benefit farmers actively working for climate neutrality or a positive climate balance.

In this connection, regulators should pay special attention to those enterprises continuing to increase their productivity for export at the expense of the climate. In summary: Climate impact in the production process for agrarian goods should indeed become one of the deciding yardsticks in a socio-ecological renewal of agriculture.

3 Biodiversity Conservation and Environmental Protection

Climate protection and biodiversity conservation in flora and fauna are equally important to a public-welfare-oriented agricultural policy, ergo for a reversal of the trend in the direction of biodiversity loss. Damage done to nature and the environment, e.g. insect mortality, decline in bird populations in agricultural landscapes of the European Union between 1980 and 2010 of 300 million breeding pairs (57%) [9], water pollution, and soil erosion [10] is socially recognized and must be politically proscribed. For this aim, individual European countries have passed strategies for environmental protection and biodiversity conservation that target farming communities (ibd.).

A major part of biodiversity losses and environmental impacts of conventional agricultural activities in Europe is connected to dynamics of agricultural structural change. From an economic point of view, this is due to concentration, specialization, automatization, and intensification taking place at individual levels as well as at sectoral levels. Since the Second World War, primary production has become increasingly industrialized. The law of success or failure seems to rule supreme and has resulted in ever-growing operational enterprises in primary production structures.

While in previous decades, investment cycles in technological innovations as well as new regulatory frameworks and incentive programs favored structural changes, a new and powerful actor has recently entered the stage: food retail. It demands and supports a new type of structural change in agricultural production. Competing with other branches of the bio-economy [11], food retail serves a broadly spread, vertical integration task and expects production changes to aid the environment and avoid further loss in biodiversity. These include, e.g. various insect protection campaigns and more importantly, efforts promoting regional and organic products. This vertical integration into area and chain and its associated regional polarization towards novel biodiversity hotspots, for instance, the Schwäbisch Hall region, gives credence to the power of economic self-organization once a market-shaping topic or an opportunity to stand out against the competition has been noted. It also meets all requirements for rural areas as to sustainable geo-biological diversity ranging from mountainous regions to the fertile northern German plains.

Future strategic national and regional plans for the promotion of biodiversity required for a novel transformative agricultural policy offer more opportunities to address regional differences with appropriate measures than mere market self-organization. Promotion of cooperative processes for the inclusion of regional strategic rural sustainable development concepts with special focus on increasing biodiversity might be one possible route. This could be in the form of a bottom-to-top participation process (bottom-up) with all relevant stakeholders, including the growing urban–rural connections, in an increasingly more urbanized world [12].

Financing and promotion of this kind of rural development require funding especially for environmental, biodiversity, and climate-relevant contributions. The Scientific Advisory Council for Agricultural Policy, Nutrition and Health, and Consumer Protection at the Federal Ministry of Food and Agriculture issued a position paper entitled "For a Common Agricultural Policy of the EU in the Public Domain after 2020". It stated accordingly:

"The Advisory Council recommends:

Promotion of biodiversity protection in open landscapes within the framework of the nature protection network Natura 2000;

In addition, member states are required to adjust their nationally planned frameworks to provide at least an amount of funding equal to the Greening Premium, i.e. 30% of current direct payments;

Expanding current tailor-made tools for different natural habitats, adapting them to agricultural and climate-protection measures, and increasing their budgetary provisions. The challenges presented by target-oriented measures concerning biodiversity protection and structural elements of landscapes have to be taken into account, while keeping administrative expenses down, maintaining inter-operational cooperation and spatial design of extensively used areas. In particular:

Incentive instruments for regional control of environmental and climate-protection measures will be applied more frequently, e.g. premium and bonus payments distributed according to soil quality, or for interlinking priority biodiversity areas;

Goal-oriented compensation models will be developed further;

The development of collective approaches for environmental and climate protection will be accelerated. The Dutch model of collectively organized and regionally coordinated agreements on nature conservation might serve as a role model"[12].

In this context, it is useful to point out the social dimension of sustainable development: Cooperative actions like biodiversity partnerships or fauna, resp., flora care cooperatives are especially equipped to bring individual community farmers together, while including other partners from nature and environmental protection organizations and local administrations. In this way, unique features that distinguish localities or communities could be economically valorized and linked, while aiding the establishment of new value chains, which would create new social commitments, ergo: strengthen the region's social capital.

However, this requires the political creation of structures for participatory regional management equipped with institutional moderation, mediation, and coaching competencies. Without the institutionalization of networks where exchanges of ideas and joint learning processes are possible, without participation, local and inter-municipal networking, there will be no local and regional rural development for biodiversity and environmental protection. In the future, vital and resilient rural areas will increasingly need farmers who not only produce raw materials, but who are recognized for their services rendered for environmental and biodiversity protection, and who will be remunerated for these services within the framework of preserving cultural landscapes.

4 Food Security in Times of Digitalization

The guiding concepts of climate protection and the protection of the natural environment combine two of the three public service-oriented areas of an agriculture that will be transformed by 2030. In an ecologically renewed social market economy, the subordinate targets in these fields have to be attained simultaneously with food security for a growing world population.

Parts of these third subordinate targets have been achieved. Calorically speaking, the productivity of globally active farming is sufficient to feed all of humanity and will even feed 10 billion people worldwide. Still lacking is a fair distribution of food or fair global access to food as well as a reduction of crop losses and prevention of food waste [6]. Successfully tackling these sub-targets politically, which contribute directly to long-term food security, would not increase pressure upon soil, water, plants, animals, and humans, as inherent in continuous efforts at increasing productivity in agriculture. Politically promoting improvements with regard to fairness, crop preservation, and food production instead of destruction would reduce pressure on agriculture for continued exponential growth for human food security until 2050.

Capital and labor resources might then be freed up for intensified agro-ecological restructuring of agriculture. On the one hand, agro-ecological cultivation practices have to be advanced for each individual region. Where technical elements are utilized (machines, data technology, biochemical substances), they must be tested as a new stage in the co-production of human labor, natural production conditions, and scientifically proven or culturally traditional know-how and adapted to regional conditions. This initial additional effort requires financial incentives. On the other hand, additional investment capital will be needed for the digital transformation of rural areas. Digitalization is considered an essential driver of an overall market-based development of agriculture, the environment, and rural areas [13]. Politically, everything possible should be done to expedite digitalization of the value chain pertaining to food production, processing, and marketing. This includes fast Internet access for enterprises active in the field of food production. And it necessitates public authorities researching advanced techniques in precision farming as well as promoting any technologies which make an area-based, site-related agriculture working in natural cycles fit for the future, or enables an ecological modernization.

It is becoming increasingly clear that digitalization in "precision livestock farming", i.e. with regard to the production of animal-based products and animal welfare, presents significant advantages for more efficient production. Ventilation systems, automatic feeders, milking robots, and robotic barn cleaners and other measures for improving animal welfare and environmental protection are easier to manage. Sensors and algorithms geared to animal welfare aid in gathering specific data (e.g. patterns of movement and activity, feeding and drinking behaviors) and assist in improving the handling of animals with the goal of achieving a more animal-friendly type of husbandry.

Measures of precision agriculture have been used to optimize plant production processes, for instance as far as fertilizer use, soil monitoring, and application of pesticides are concerned.

In Germany, as an example, digital solutions are already in use at more than 50% of German full-time farms; 39% use digitally operating machinery for soil preparation, seeding, and harvest; 51% utilize digital feeding technology; and around 40% use robot technology for barn cleaning or milking [14].

Increased global digitalization will contribute to a faster implementation of environmental and nature protection goals and improvements in animal welfare and climate protection as demanded by society at large. However, this requires investment support from the public sector. Above all, it requires business models for farmers, whose data is used by agricultural machinery manufacturers. If agriculture is integrated into the digital economy contributing data to service industries, the third sector of contemporary economies, it has to yield monetary returns in the future as a source of income for farmers.

Enhanced digitalization and relevant information available to all market participants will change activities assuring food security in all parts of the world. In its extreme transparency concerning yields and prices available everywhere, it is the key opening up the way to truly connected world markets. The international agricultural commodity trade has been using powerful information and communications tools for some time, e.g. to organize food streams. In addition, another accelerating technology for the transformation of agriculture is emerging, particularly with a view to the fifth generation of mobile communications. During the twenty-seventh Hülsenberger Discussions in 2018, Gerhard P. Fettweis and Norman Franchi summarized the importance of the networks for digital agriculture in the following theses:

These discussions also dealt with legal challenges of agricultural digitalization and its concomitant need for political intervention. Using the example of data ownership and protection, José Martinez stated, "the following topics carry legal risks: Protection of personal and—moreover—company-related data, provided they have not been classified as trade secrets. In cases like these, data protection has only been sporadic. Moreover, civil law seems problematic in its classification of data, given that there is no data 'ownership' under German civil law. Intellectual property rights protect intellectual creations, but stop short of protecting mere technical data or geodata from agricultural enterprises. Additionally, there are significant problems with classifying declarations of intent issued by machinery, and with regard to liability for errors in the recording or evaluation of data. European and state regulators have not found adequate solutions so far, given the exploratory nature of this field. These problems will have to be solved in bilateral agreements" [16].

Therefore, Martinez is correct in his demand for European regulators closing known regulatory gaps, which lie in liability law, in the protection of operational data, and in contract law [16].

Scientific–technological solutions in agro-ecology and digitalization, and combinations thereof, will play a decisive role in the necessary ecological transformation of agriculture within the framework of social market economy. The creation of legal and investment security tools will become just as important in this respect as organizing the world commodity and food trade within norms of fairness and sovereignty [17].

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Bavaria in Transition: Changes in the Water Balance Due to Man and Nature

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Abstract The interlinkages of anthropogenic activities and phenomena of change are the subject of countless considerations, mainly with the aim of predicting further developments. Diversity in interpretation exists, in particular in the attempts to explain cause and effect, in the choice of reference points or in the evaluation of compatibility and resilience towards changes. Ultimately, behind all this, the question is whether the changes observed are "good" or "bad" for us humans. For years now, evidence has unfortunately been growing that critical changes in the environment can jeopardize the positive fruits of progress, i.e. our general prosperity. Especially the younger generation is seriously concerned for its future. The starting point for all considerations is data. This chapter presents facts and figures on developments over a period of several decades. The area under consideration is the German federal state of Bavaria. Discernible is a double change in the nature-related parameters. On one hand, anthropogenic activities show an influence on nature, on the other hand, natural processes also change the ecosystem balances. Both processes overlap each other and, through this, cannot always be separated clearly.

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1 Introduction

We are experiencing a clearly discernible global change. Much of this we perceive as positive, such as more communication, commerce or comfort. On the other hand, the interdependent phenomena of changes in the available water resources, Climate Change, a loss of biodiversity and the increasing social injustice [21], belong to the identifiable critical, sometimes crisis-inducing developments. The ubiquitous spreading of substances from anthropogenic emissions is equally indicative of an era in which humans have become one of the most important influencing factors on the biological, geological and atmospheric processes on the Earth. Consequently, the term “Anthropocene” was born [6].

Up to today, our success and our prosperity strategy lay in the enormous technical progress and the concomitant technical adaption measures with which we have adjusted the environment to our needs. These technical adaption measures frequently lead to irreversible dependencies on these now ‘vital’ systems, the maintenance of which binds future generations permanently. In addition, the self-evident nature of the systems reduces resilience and decouples the human–nature relationship (“There is no such thing as water shortage in Germany!?”). Further technical adjustments will be necessary, particularly in view of the fact that undesirable side effects and even failing ecosystem services have to be compensated for in a technically complex and expensive manner. The technical capabilities of humans now appear to be without limits. With the increasing ability of mankind to reshape and influence the world, the clarification of the question “Where do we want to go actually?”, and only then the question “What tools do we need for this?” becomes even more important, indeed essential for survival. However, technological progress still seems much more tempting solely because of the progress or economic success. The overshaping of the world then results almost by chance, as a waste product of technologies and uncontrolled technicism.

2 On the Complexity of Identifying Cause and Effect as Well as Good and Bad

Hypothesis: There is no effect without side effect (and no “good” without “bad”). Most of the changes we observe in our environment can be traced back to intentional cultural achievements and related interventions in our Earth system or are side effects from such cultural achievements. We have considerable pride in the technical possibilities that Homo Sapiens has created, starting with the taming of fire and inventing of the stove. Nevertheless, there are increasing signs that the pot, which we have placed on the energy system Earth, is just beginning to overboil and is too heavy to be lifted quickly enough to avoid overboiling. In other words, to the joy of the accomplishments of the modern world, there is an increasing concern that the side effects are so grave, that they are running out of control and endanger our cultural achievements. At the latest, that is an opportunity to reflect on what we are doing.

However, we do not want to question our accomplishments without reason—the facts gained from nature observation must therefore be examined for their significance. The interpretation of such data is noticeably difficult. On the one hand, the causes of change are subject to both, natural and also anthropogenic influences. Effects overlap each other and are not assignable just like that, neither causally nor timely. On the other hand, a structure of data collection, a choice of measured parameters and an application of assessment algorithms are always determined by the assumptions of an acceptable target state. In other words, Where, what and how precisely should one check? And ultimately, the question always remains whether the observed changes are "Good" or "Bad", whether they are even relevant, but with the acceptable collateral damage of useful or even necessary cultural achievements or no longer acceptable, since coming along with changes endangering the cultural achievements.

Unfortunately, this assessment is often still a matter of the point of view (cui bono?) or even of the assessing generation—what do we already know about the future? How facts and their assessment attract attention at all is, therefore, also determined by the political discussion of the aims. In the case of the human–nature relationship, the "sustainable economic development" applies at the level of international law, being a principle the world community has agreed on decades ago [19]. Pursuant to the definition of sustainability [20], the central spheres of action were agreed as a result of an international debate on development and environmental politics: Rio Declaration of 1992 with Climate Protection Convention, Biodiversity Convention, Forestry Protection Declaration. Three decades after the Rio Conference, the key subjects elaborated at the time proved to be permanently relevant and inseparable.

Connected elements are the large commons, water and soil. Their protection is the basis of sustainable, environmentally compatible growth. The environmental knowledge required for this has grown steadily since Rio.

Along with the component of time, the behavioural component also plays a role. The precautionary principle introduced with the first Environmental Action Programme of the EU in 1973 implies a certain foresight. Precaution is then to determine the action when "scientific evidence about an environmental or human health hazard is uncertain and the stakes are high [9]."

The potential of understanding the environment should thus have increased generally. Therefore, it is all the more remarkable that for quite some time, a kind of political counter-movement has gained ground, not only in the USA, which might actively negate the restrictions of human action through environmental system limits. Paradoxically, the amount of data volumes and the increasingly specific consideration within the widely ramified individual compartments facilitate such political standpoints: It is admittedly difficult to keep track of the major inter-relationships.

Leaving aside the fact that the behaviour in environmental practices or environmental policies often does not follow the precautionary principle, it remains important to know more about the actual effects and side effects of human activities and, when planning for achieving objectives, to be able to estimate and take trends in natural environmental developments into account. Observation should not be made from dogmatic points of view but rather facilitate changes to be discernible, and with this is also interpretable and socially acceptable, being an operational framework for action.

As an example for this approach, the following sections will describe observations in the changes in the water balance in Bavaria.

3 The Anthropocene I: Facts Climate Change in Bavaria

The most well-known and most discussed "external" manifestation of the Anthropocene is Climate Change. Analyses on the Climate Change from the co-operation project "Climate Change and consequences for water resources management" KLIWA (www.kliwa.de), established in 1999, attest for Bavaria that the natural system is subject to a change. Alongside detectable changes in climate parameters themselves, such as air temperature or precipitation, these changes also impact the natural water balance. Thus, changes in flood runoff patterns can be identified as increasing local heavy rainfall or longer, large-scale dry periods. All this signifies considerable challenges for nature and people in Bavaria.

These changes also bring along a need to adjust the recording and analysis of environmental parameters. Monitoring networks, measurement grids, measuring ranges, measurement frequencies or methods of measurement must be checked, and, if necessary, be adjusted. One example is the measurement grid for the recording of precipitation using pluviometry, which can no longer depict the increasingly local heavy rainfall events. Local heavy rains literally fall through the grid. Here, the disadvantage of discontinuity of the time series resulting from the rearrangement in monitoring, has to be put up with.

3.1 Temperatures and Precipitation

Air temperature was measured since 1881 by the German Weather Service (DWD). The ten warmest recorded years in Bavaria are almost without exception in the twenty-first century; 2018 is to date the warmest year of the time series. Between 1931 and 2015, the mean annual temperature in Bavaria has already warmed up by almost 1.3 °C. The temperature increase for the hydrological winter half-year (November–April) is with 1.4–1.6 °C slightly higher than for the hydrological summer half-year (May–October) with 0.8–1.1 °C. Along with the air temperature, the temperature of water bodies also has increased, on average since 1980 by some + 0.5 °C per decade.

Besides temperature, the changes in precipitation are of great significance for the water balance in Bavaria. Considering the complete year, as well as autumn, winter and spring, the precipitation for the period 1931–2015 has increased by 5–15%. In the summer, on the other hand, a reduction in the same magnitude is measurable. Consequently, a redistribution within the year clearly is visible. Thereby, for the winter half-year, the spatial focal point with the greatest changes lies in Northeast Bavaria with increases up to 22%. There the daily maximum precipitation totals in the winter half-year increased locally even up to 33%. In the summer half-year, the trends are without any significant development. These chances remain clearly not without consequences.

From time to time, there are great "hundred year floods" in Bavaria [14], but with a conspicuous clustering around 1999, 2005, and 2013. At the end of May 2016, as an event with even rarer observed occurrence three weeks of torrential rainfalls from France to Hungary flooded many areas within the shortest time to a catastrophic extent, including two dozen events in Bavaria with the sad apex in Simbach am Inn with several casualties and death. In June 2018, there was heavy local precipitation in the Bavarian Forest. What is the connection between Climate Change and the short-period convective precipitation? The warmer the air, the more water the atmosphere can absorb. With every degree Celsius, the precipitation intensity increases by up to seven percent. The increase can even be higher with the predominantly summerly showers. There are first signs in the measured data that the highest rates of precipitation, which in summer can fall within one hour, have grown more intensive. More precipitation in the winter months at the same time leads to increased erosion, particularly on uncultivated fields. Auerswald et al. [1] came to the conclusion that the rainfall erosion has almost doubled between 1962 and 2019, and will further increase considerably. Likewise, Auerswald et al. [1] came to the conclusion that the increase in stream and ditch erosion, which in Bavaria 30 years ago had been practically unobserved, is a clear pointer to the problems, which arise through changes, which affect the complete catchment areas. The resilience of landscapes due to wide-area changes is clearly exceeded through this. Along with the loss of valuable arable soil, the pressure on water bodies with regards to culmination and eutrophication increases.

In the recent past, however, the years 2003, 2015 and 2018 were also very dry years. The evaluations of long-term changes in weather conditions show that the probability of a dry, hot summer and an extremely dry vegetation period in southern Germany century has increased by a factor of five when compared to the period before the 1970s. The impacts of such dry periods are to be felt in the rivers and in the groundwater and represent a grave influence on the water balance, which ultimately can even have a social impact (e.g. transition from rain-fed agriculture to irrigated agriculture).

3.2 Statistic Changes on Floodwater Flows According to the Present Status

Evaluations show a tendency towards increasing floodwater flows [11]. In particular, for the entire year, and for the winter half-year, the measured highest values between 1931 and 2015 have increased. From the 60 evaluated water gauges for Bavaria, approx. 70–75% show a rising tendency. Over the summer, half-year increases exist at approx. 65% of the water gauges. With the assessment of the trends, there is, however, a limitation in that only a small number of the calculated trends are statistically significant. The measured values, in any event, show that approximately from the year 2000 the floodwater flow behaviour changed. The initially available floodwater trends up to the year 2000 were already falling with a data extension to 2010 and they show a clearly moderated increase. The further data extension to 2015 confirms this decline of the trends and shows a further, albeit smaller reduction of the still increasing floodwater trends.

3.3 Statistic Changes in Discharges and Groundwater Reservoirs to the Present Status

More frequent dry periods should also portray themselves in the measured flows and, time displaced, in the groundwater conditions. If one considers the changes of the low water flows at 71 Bavarian water gauges [12], then the determined trends up to and including 2015, however offer only a limited message with regard to Climate Change. The measured flows are not only characterised by the climate (through nature) but also significantly especially in the low water (through humans) due to hydraulic engineering and/or water resource management measures such as, for example, water abstractions and water supply, reservoirs and land improvement measures (drainage of wetlands and moors by means of ditches and drains). With the consideration of the annual low water flows, an increasing trend can be recognised in almost half the water gauges for the complete year. Solely 10% show a falling trend. Also in the summer half-year, a third of the water gauges indicate an increasing trend, while a falling trend is discernible also at 10%. A pattern in the distribution of the decreases and increases cannot generally be determined in Bavaria. Thus, the trends of the low water parameters show generally an increase of the low water flows, conditioned also through the anthropogenic water resources management of the water bodies. However, at the end of November in 2018, many hydrological water gauges across Bavaria showed very low flows or even new lowest values. Some smaller streams dried up in sections, in part also completely.

The impacts of the dry periods show themselves clearly in the groundwater. The surface-near groundwater usually reacts very quickly to drought. The deep groundwater has a longer memory and portrays the results of the dry phases of the previous year. For example, the dry summer of 2015, or the precipitation of the winter of

2016/17 led to the fact that, in all, 79% of the measurement sites in Bavaria's low water information service (www.nid.bayern.de) were low or very low, a new record. For Bavaria, 65 measurement sites of groundwater levels and spring flows with long monitoring series were assessed. A large number of these measurement sites (72%) for the period 1951–2015 show a long-term tendency towards the reduction of the mean groundwater levels and spring flows. Since 1990, at only 32% of the measurement sites do reductions occur, while at 42% of the measurement sites stationary behaviour is observed. In the mean annual cycle, there are also changes. Thus the annual maximum of the groundwater levels and spring flows in Bavaria at 52% of the measurement sites occurs earlier in the year (on average by 0.5 of a day per year), which can lead to an extension of the summery low water periods. The seasonal changes overall can be easily brought in line with the known changes of the precipitation and water supply regime. There are still no statistically significant changes with most of the groundwater and spring flow measurement sites with regard to the beginning, end or duration of deficit phases.

3.4 Climate Future

Changes in the climate, and in the water balance, are in the meantime verifiable through measurements. For the Bavarian water resources management, there is naturally the question, what is going to happen in the future? Will the existing trends continue? For what developments in the future will an easing or an intensification arise, from which there will be a call for action?

The climate projections agree that temperatures will also increase in the future. Furthermore, the annual distribution of the precipitation will continue to change. Summers will presumably become drier, the winters wetter. Overall, in the future, we must adjust to more frequent and longer dry periods, which will be interrupted by intense heavy rainfall events—with the corresponding impacts on humans and the environment.

For the water balance, the results of the climate projections mean that, on the one hand, the floodwater flows can increase further, particularly in the winter half-year. On the other hand, due to increasing dry periods, low water situations can intensify, accompanied by growing evaporation due to higher temperatures. Model calculations show that the number of days, during which the vegetation is subjected to a water stress will increase. For the groundwater, recharge declines for the whole of Bavaria have to be reckoned with as well. These are clearly more distinct in south Bavaria than in north Bavaria.

The forecasted changes signify potentially a fundamental change of the water resources management parameters to more extremes in floodwater events—as particularly in low water events, with all resulting ecological, social and economic consequences. The necessity for adaptation resulting from this, however, will have effects and side effects on their own.

4 The Anthropocene II: Over 250 Years of Influence on Natural Waters

Comprehensive changes of the complete network of bodies of waters took place, particularly in the Anthropocene, enabled through the power of machines, in order to ensure sustenance, to acquire residential areas and to protect against flooding, to enable the transport of goods and wastes and to ensure the water supply to towns and communities. In the shadow of the industrialisation in the last third of the nineteenth century, by means of widespread land improvement and intensive cultural engineering, draining of the soil and rapid flow of water was achieved (see Fig. 1). Complete river systems were subjected to correction (Fig. 2). Urbanisation, combatting of diseases and production targets led to the "correction" of Nature. The river engineering and agricultural construction measures have profoundly changed the map and landscape image of Bavaria.

At this point, you have to imagine that already thousands of years ago a similar drastic, if not greater, interference in the water balance took place in central Europe. The great clearing of woods and forests took place up until the end of the fourteenth century (see Fig. 3). The wooded area was just about halved and has, since then, stayed more or less the same at a third of the country. In particular, in the Mediterranean regions, the woodlands (sclerophyllous plants) had, however, already considerably earlier, been used by the Greeks, Carthaginians and Romans, which had led to degradation and soil erosion. Macchia and rocky landscapes partly without topsoil, among other things, replaced the holms oak and Mediterranean forests. It was only after the

Fig. 1 W. L. Kozlowsky 1932: Agricultural (culture technology) hydraulic engineering (Historic picture from the collection of the Austrian Section for Hydraulic Engineering, Vienna)

Fig. 2 Isar correction near Freising (Left 1812, Right 1934. *Source* LfU)

side effects, such as floodwater flows, riverbed erosion or soil erosion increased that one recognised even further side effects, intrusions in the water balance.

In the middle of the twentieth century, ecological construction forms developed as "natural hydraulic engineering skills." Later, riparian areas and catchment areas were included in the planning, whereby water functions found recognition as ecosystem services. Bodies of water were perceived as structural forming entities, also and particularly in cultural landscapes. The benefits of bodies of water for people were also better understood. Thus, the second Bavarian state development programme of 1984 was carried out, and thereby "(T)he recreational activities on the water … are becoming evermore popular. Therefore, due to the increased demand, the recreational use of bodies of water is to be taken into account more intensely". For example, a "user friendly" configuration of the riparian zones was demanded. Nevertheless, the globally applicable changes of the Anthropocene, also in Bavaria, come up against an almost completely shaped surface water landscape, whose properties differ presumably clearly from the "geological-historical". This applies in particular to the systematic resilience that is the ability of the ecosystem to react to changes, regardless of which type.

With the EU Water Framework Directive (WFD) since 2009, socially agreed water-engineering measures have been implemented, which positively aim at

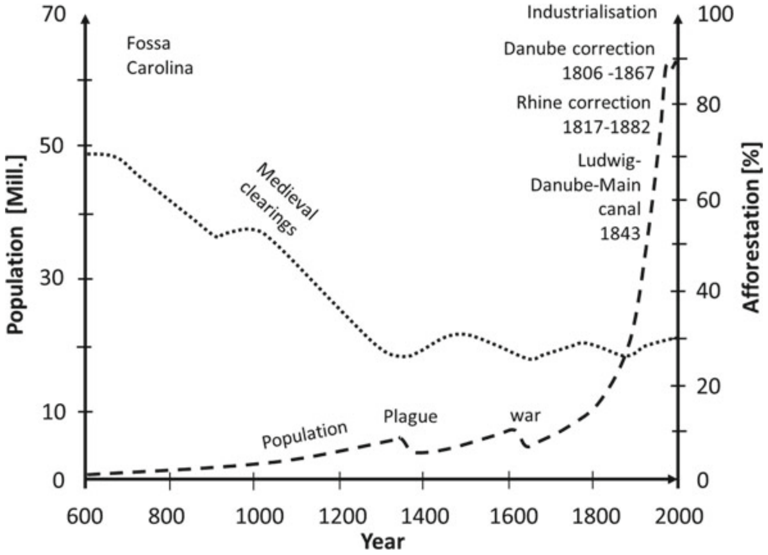

Fig. 3 Afforestation and population in Germany (Old Federal States)—Diagram: Supplemented according to Winfried Freitag (http://www.historisches-lexikon-Bavarias.de/Lexikon/Wald,_Waldnutzung)

impacting water body resilience, in part also at low water situations. At the same time, however, the economic pressure is growing on the bodies of water through the abstraction of water for cooling and diversions, through general water requirements as well as even through climate protection measures (mitigation processes) such as hydropower or cultivation of renewable raw materials.

4.1 Land Utilization

An important active factor within a water catchment area is agricultural usage: More than three million hectares of land are used agriculturally in Bavaria. These are 44% of the total area of the Free State. Two-thirds of this area are arable land, a third are meadows and grassland. With the introduction of mechanical laying techniques in the 1950s, further parts of the agricultural area were drained (land improvement through drainage ditches and drains). Agricultural drainage has an influence on the water balance, on nutrient flows and the soil structure. Along with the desired impacts on soil qualities and harvest yields, uncontrolled drainage, however, can also affect the broad water balance detrimentally: Water is not stored in the soil but rather flows off rapidly. At the same time, the groundwater recharge reduces: Water, which is not standing in the soil, can also not be percolated. Due to a lack of availability of data, these relationships cannot be quantified today. There are indications that these cultural engineering measures possibly have the greatest influence on the multi-week discharge in Bavaria [15]. At least, the past 15 years warm summers have shown a devastating effect on the soil water balance and the low water situation of the water bodies. With construction years predominantly in the 1960s and 1970s, the majority of these drainage systems today are in need of repair or renewal. With the upcoming renewal of the systems, the objective to drain off "excess" water would be, with today's level of knowledge, a subject for reappraisal. A reduction or slowing down of water discharge, at least periodically, for example through controllable drainage, is important for the water balance.

Along with a change in the water balance, dewatered and drained moors, with 5.1 million tonnes CO_2 equivalent contribute 5% to Bavaria's greenhouse gas emissions and is thus comparable to the emissions of Bavaria's refineries. According to the current level of knowledge, 85% of the originally up to 220,000 ha of moors and bogs (~3–4% of the Bavarian land surface) are used for agriculture and forestry. More than half of the moors alone are used agriculturally. With this, it is to be noted that drained moor soil suffers peat humification, whereby the organic substance degrades and is released as CO_2 climate gas (Fig. 4). Bog soils settle annually in the centimetre range and are thus increasingly unusable in agriculture. In addition, through this process, the nutrients bound in the bog soils are released and get into the underlying water bodies.

A further factor lies in the "land consumption:" In Bavaria, the new utilisation of areas for residential and traffic purposes lies at 12.1 ha per day [5]. 654 m^2 per inhabitant are in the meanwhile residential or traffic areas. Urban areas reach a high

Fig. 4 Drained landscapes (drainage ditches)

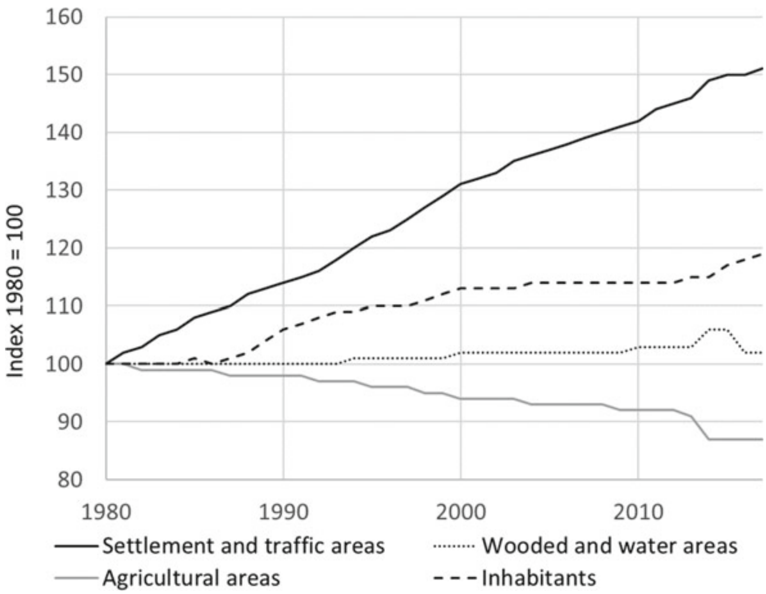

Fig. 5 Land utilisation and population development in Bavaria 1980–2017 (*Source* https://www.stmuv.Bavaria.de/themen/boden/flaechensparen/daten.htm)

degree of sealing of 23% (Ansbach) to 74% (Munich). In the rural regions, the degree of sealing lies significantly lower at 5% (Garmisch-Partenkirchen) to 18% (Fürstenfeldbruck). Results of the sealing are a loss of the natural functions of soil and water balances, in habitat, and thus in biodiversity. Storage, compensation and buffer functions are lost and the potential in local resilience. At the same time, unfavourably situated residential areas are often drained, which leads to “infiltration water” in the sewer and to a lack of regeneration in the groundwater (Fig. 5).

4.2 Uses and Extraction of Groundwater

Overall, the pressure on groundwater is on the rise through anthropogenic usage and Climate Change. The quantitative change is gaining in brisance especially in dry years such as 2018. To a great extent, the drinking water requirement in Bavaria is covered by groundwater. Currently, the water supply is assured even in dry areas of northern Bavaria. 85% of Bavaria’s population are supplied with water without restriction, 12% restricted and about 3% severely restricted.

The security of supply, however, is not always justified by the natural local resources, rather relies also on the adaptation measures of the public or communal water resources management. Through the build-up of a publicly subsidised long-distance water network (Franconia as well as Bayerischer Wald) until the end of the

1960s, the drinking water resources in Bavaria could be managed in a way that the climatically conditioned changes of local groundwater resources were barely noticed by the consumers of the drinking water (water contribution from long-distance supply in 1972: 6 mill. m^3, 2013: 32 mill. m^3). Currently, there is a requirement for the delivery and distribution of ca. 80 mill. m^3 drinking water in Bavaria's north, in order there to balance the low precipitation and lacking storage capability of the soil. To that end, some 30 mill. m^3 per year are supplied through transfer from the Danube valley and 12 mill. m^3 per year from one of the two states' drinking water barrages (Mauthaus). In addition, there are 2,400 local storage tanks for the drinking water supply (ca. 2.5 mill. m^3 volume) in Bavaria's local communities for short-term balancing.

An additional pressure on the water resources arises through the increase of irrigation in the agriculture sector. In Bavaria, 2,950 agricultural operations have the option of irrigating in total 52,800 ha. With this, only roughly a third employs the water-saving technology of drip irrigation [7]. According to first estimates, the water requirement for the complete agricultural sector in Bavaria in the medium term comes to 58 mill. m^3, whereby the greatest part with 48 mill. m^3 falls to small-scale priority areas. A database on this is currently just being built up, so that no reliable figures but rather these estimates are available.

4.3 Agricultural Production

The irrigation requirement is only one of the effects of the intensification in agriculture. The grain yields since 1950 of ca. 2.1 tonnes per hectare (t/ha) to ca. 7.5 t/ha have more than tripled. Despite a decline of the cultivation area by ca. 15% the total yield is tripled (Fig. 6).

About a third of the total production of the German agricultural sector is exported, and that although in Germany, as in the EU, no subsidies have any longer been allowed

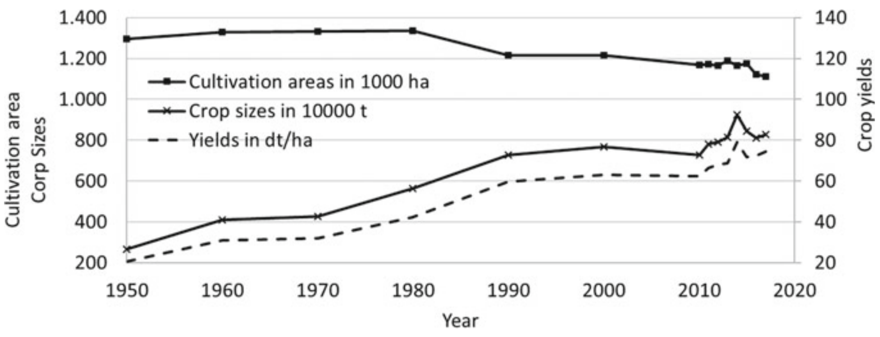

Fig. 6 Cultivation area, crop yields and crop sizes for cereals in Bavaria since 1950 (*Source* Bavarian agricultural report 2018, StMELF 2018)

since 2013 [3]. In this connection, the recipient markets are described as well-funded and Germany as production willing “favourable region”. The German agricultural exports account for 5.6% of the share in world export. Thus, Germany ranks third in the agriculture exporting nations worldwide (after the USA and the Netherlands). The German agriculture exports between 2000–2002 and 2013–2015 have more than doubled (+125%). In 2017, across the whole of Germany, animals or animal products to the value of some 21 billion euros have been exported [7]. The German Federal Ministry of Agriculture (BMEL) speaks of a responsible export strategy. This assessment is apparently coined on the selection of the recipient markets, and the consideration that one trades little with developing countries and then rather with imports. The BMEL postulates sustainability in the agricultural sector based on the assessment that in the past decade the agricultural production could increase by 25%. At the same time, the nitrogen surplus sank by 15%, and up to 2030 is to sink further to ca. 70 kg/ha. Based on the German Federal Environment Agency 2009, an integrated strategy for the decrease of nitrogen emissions and on the special appraisal of the German Federal Government Environmental Council of Experts of January 2015, however, compared with these, the target value for the nitrogen surplus at a maximum of 50 kg/ha would be necessary and to aim for in the short term. Other emissions from animal farming must also be reduced (ammoniac in accordance with the EU-NERC Directive or according to the German Federal Government climate protection plan 2050 on nitrous oxide and methane emissions from animal farming and manuring).

The acreage footprint of livestock in Germany, for fodder production alone, is given as cattle 6,000 m^2 and pigs 700 m^2, per farm animal. With an export share of one-third, almost 40 of 118 million tonnes of animal fodder from domestic production should be calculated as part of the export burden concerning the water requirement or the use of pesticides. Or, also concerning the nitrogen surplus, because once the available agricultural areas cannot be increased, each increase in production in animal husbandry is at the expense of the disposal problem for organic wastes.

4.4 Retention Space and Transfer Systems

The classical measures for the balancing of water budgets are barrages and water storage systems in any form. Through the construction of storage and transfer systems, the bodies of water for flood retention, the raising of low water and as drinking water have been optimised. Since the 1950s, over 500 mill. m^3 of storage space in 25 large barrages have been created (ca. 210 mill. m^3 for flooding, ca. 280 mill. m^3 for low water, ca. 35 mill. m^3 for drinking water) (Fig. 7).

A positive side effect of the interventions of water management is the expanded social function of the bodies of water through a corresponding increase of recreation activities, e.g. on the river Isar (supported by the Sylvenstein storage) or on the Altmühl, Brombach and Rothsee lakes, which in their current recreational function, first resulted as part of the Danube-Main transfer system.

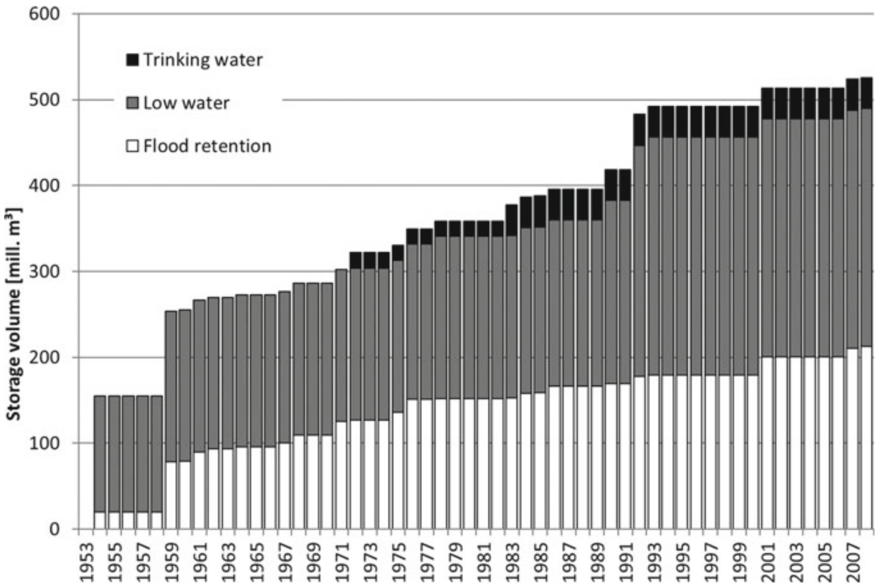

Fig. 7 Development of the retention space in Bavarian barrages for drinking water, low water, floods

This transfer system and with this the supply of the dry Bavarian north is one of the most important interventions in the Bavarian water balance. Here, water is transferred via the Danube-Main canal from the Danube region to the north into the Main catchment area (for example in the dry year 2015 ca. 250 mill. m^3) and thereby in part stored in barrages. The Franconian lake landscape came into being. How strong this anthropogenic impact on the water balance in Franconia is, is shown by the example of the Neumühle water gauge on the Rednitz. For the inhabitants, even after long dryness in 2018 or spring 2019, no low water is to be observed. With this, the non-local share from the transfer system can account for the predominant share of the water observed locally, in the example from over 50% (Fig. 8). Currently, Climate Change and its impacts on the water balance bring the water availability, and, also in the extraction regions of the transfer, occasionally into critical areas; the controllability of the storage space becomes more difficult.

Along with the large barrages for flood protection many other governmental flood protection measures have been implemented (investment total since 2001 almost 2.5 billion euros). Nevertheless, no flood protection measures can offer 100% protection. Extreme events, which with Climate Change are more frequent and heavier, have already led in the past to immense damage and fatalities, for example, flooding in 2013 (1.3 billion euros in Bavaria) and the flash floods in 2016 (1.25 billion and 7 fatalities alone in Lower Bavaria). About 550 small reservoirs, which mainly belong to the communities, also serve as flood protection (in total ca. 50 mill. m^3 retention volume). Viewed statistically, with this there is in every fourth Bavarian local authority a flood

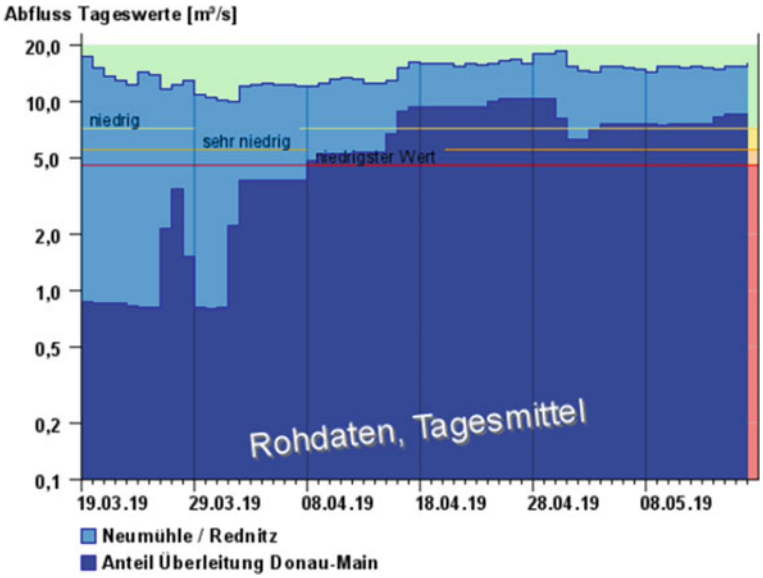

Fig. 8 Share of the transfer water (dark blue) at the overall flow at Regnitz (Gauge Neumühle / Rednitz)

retention reservoir. Nevertheless, not always has new retention volume been created. In part, these reservoirs serve also as adjustments, i.e. as compensatory measures against deterioration in the flood retention due to anthropogenic land use.

Structural changes have also been undertaken by people directly on the bodies of water. Structural changes to channels (river morphology) and to riparian strips influence the water ecology and also the flow times in the bodies of water. Straightening and diking accelerate, impoundments in the rivers and renaturing retard the flow of water. This leads to an alternation of the anthropogenic effects and countermeasures, not the least also with the storage control (see above). A natural flow behaviour can no longer be seen on the larger rivers in Bavaria. How sensitive and in part ambivalent interventions can be, is shown in a desired retarding in the flow, with which the simultaneous lack of shading on bank border strips using natural vegetation, also affects the temperature of the waters. It results in a more rapid warming up, less oxygen concentration and thus less resilience with regard to eutrophication.

5 The Anthropocene III: Emissions

A simple to determine and relevant anthropogenic parameter is population growth. The population in Bavaria since the 1950s has increased by 49%, from 9.2 mill. to just 13 mill (LfStat 2017).

How the changes in society influence the environment is shown in the following examples.

5.1 Municipal Wastewater Treatment

The first area-effective adaptive strategies were formulated more than 50 years ago in order to protect the aquatic environment. One focal point from the beginning was also the reduction of eutrophication. Via the construction of wastewater treatment plants, the share in heavily polluted bodies of water since the 1970s could be reduced from 25% down to 1.2% in 2001. The connection rate to the sewer system has been increased from 10% in the 50s and today to 97% (Fig. 9). For example, in the meantime, through this, the phosphate content in the bodies of water has again decreased considerably (Example: Bodensee [Lake Constance] Fig. 10).

New assessment criteria from 2001 for water quality no longer consider only the saprobient or trophies of a body of water, but rather further ecological and chemical parameters. The conversions in the indicator system currently complicate comparisons or statements on trend.

Since approximately 20 years, the number of municipal wastewater treatment plants has again reduced (Fig. 11), which can be traced back to mergers of larger, efficient plants. This concentration process towards central, more highly engineered wastewater treatment plants has for the discharge into bodies of water, along with the higher treatment performance also quantitative effects on the flow in the water

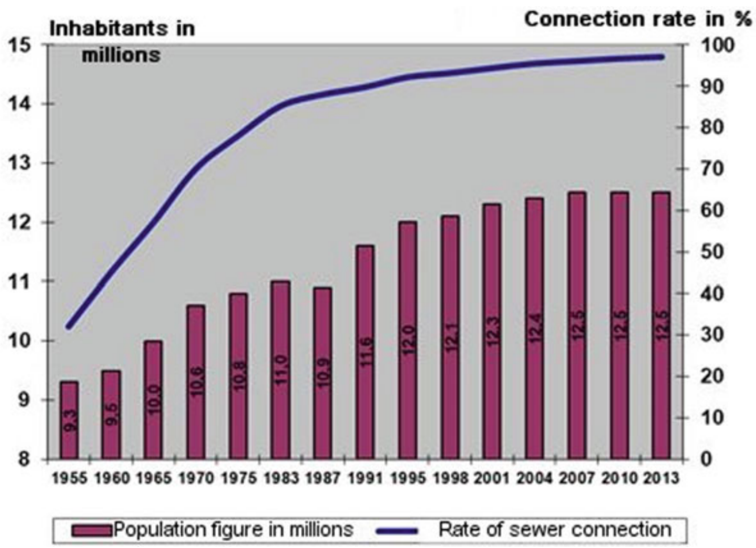

Fig. 9 Rate of connected wastewater treatment plants and population development (*Source* LfStat)

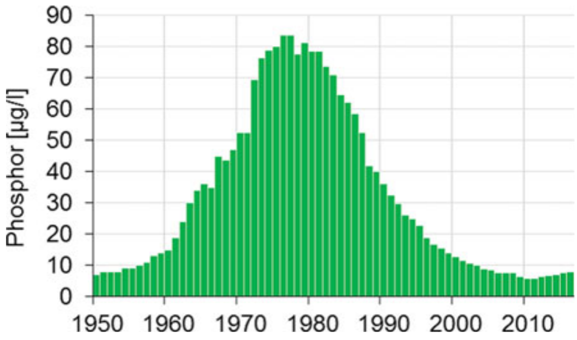

Fig. 10 Total-P (phosphorus) annual mean values (centre of lake, volume-weighted) in the Bodensee-Obersee from 1950 to 2017

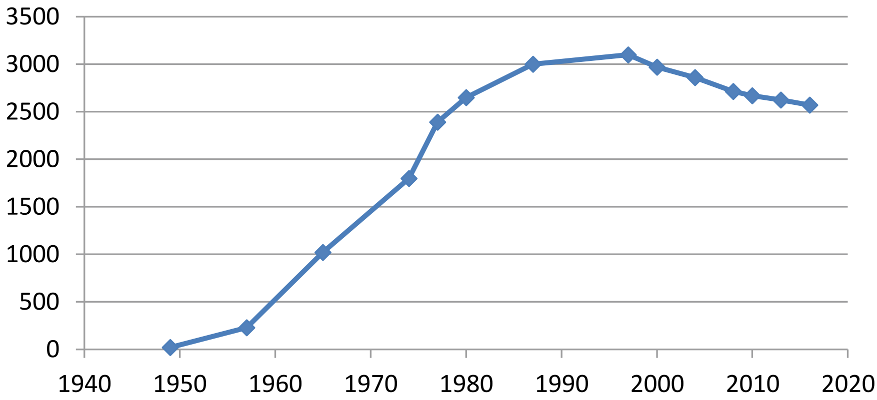

Fig. 11 Number of wastewater treatment plants in Bavaria 1950–2016

bodies. Small wastewater treatment plants up until now have often discharged into backwaters , have ensured a continuous increase of the flow-off, sometimes in low water situations even for the sole basic flow, which improved the resilience with respect to longer periods of drought. The discharge from larger, central wastewater treatment plants takes place into larger bodies of water, due to the required mixing ratios. With mergers of wastewater treatment plants, this leads to a nutrient easing for small bodies of water.

With the discharge of treated wastewater, in addition to nutrients, also the already mentioned trace substances or germs have entered the bodies of water. Parameters, which even with larger plants have not been reduced specifically up until now. In fact, they can accumulate precisely there, because the catchment areas of the wastewater treatment plants grow and with this, along with domestic greywater, ever more wastewater from other branches is piped in. The results are discernible in low water periods even in larger bodies of water. Examinations of samples from bank filtrate-influenced groundwater show a greater impact from trace substances than was previously presumed [18]. In order to counter these impacts, there is today an increasingly discussion on the establishment of further "fourth" treatment stages for the removal of trace substances in wastewater treatment plants on bodies of water with unfavourable mixing ratios and/or other sensitivity.

In Bavaria, the discharge of wastewater takes place, historically conditioned, mainly in the for Germany typical combined system: From over 60% of drained areas of land precipitation water is discharged together with greywater. Through the discharge of stormwater via the wastewater treatment plant or combined watersewer overflows into the surface waters, precipitation, which falls on sealed surfaces, is lost for groundwater recharge. With 11% of sealed land area with ca. 50% degree of sealing, due to the combined sewer system in Bavaria, no groundwater recharge takes place on a calculated 2,340 km^2. The long-term impact on the groundwater recharge cannot be quantified, but contributes, at least in urban areas, to a lowering of groundwater levels. With the change of the German Water Act in 2010 and the preferred commitment to the separate system with local percolation of stormwater, the groundwater recharge is improved and flooding hazards following rainfall events are curbed: However, diluting effects are also reduced. With this, the example of wastewater shows graphically how complex the mutual dependencies can be, which result from the interventions of humans in the water balance and in the water quality.

5.2 "Problem Child"—Nitrogen Surplus

The nitrogen balance, which increased into the 1980s, could be reduced in the meantime again to the level comparable with that of the 1960s (Fig. 12).

The relationship between the agricultural N-balance, respectively, N-surpluses and the loading of water with nitrogen is complex. However, it is currently considered as the main reason in many places for being poorly assessed groundwater quality within the sense of the European Water Framework Directive. Assessed according to the Water Framework Directive, the groundwater quality is crucial for a poor condition overall. The quantity, which has already been discussed, is currently still the subordinate problem in Bavaria. Table 1 shows the nitrate load of the Bavarian groundwater. Up until now, there has been no detectable improvement from 2000 to 2016.

5.3 Nitrate Load

The primary aim of the adaptation measures in order to be able in the future to use groundwater for the supply of drinking water to the population, is therefore currently a further reduction of the nitrogen balance. Nitrogen is considered, not only with groundwater protection, as an urgent environmental problem [16].

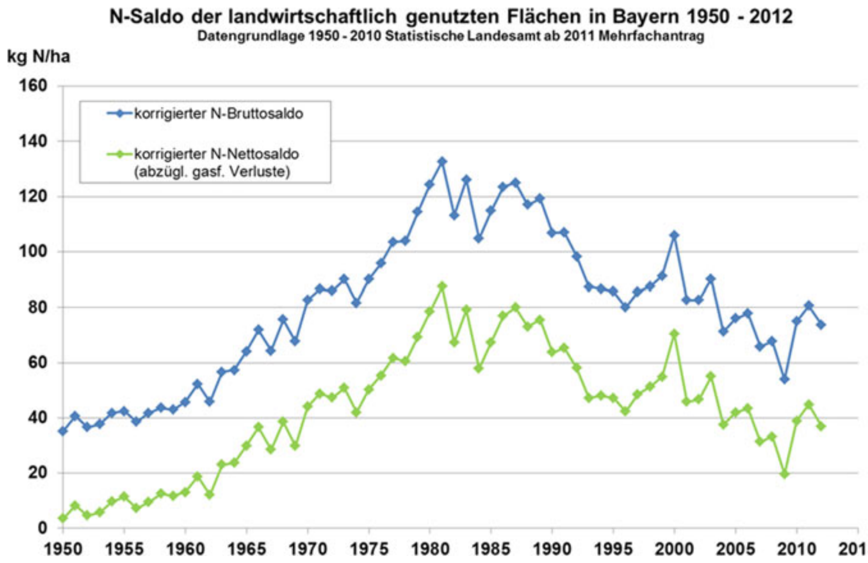

Fig. 12 Nitrogen balance of the agriculturally utilised areas in Bavaria 1950–2012 (*Source* [7])

Table 1 Share of the investigated measurement sites of the federal state measurement network, groundwater characteristics (2000) and of the WFD overview measuring network (2016) on the nitrate loading classes (*Source* Bavarian Information system water resources management—INFOWas)

Number of measurement sites investigated		2000	2016
		268 (%)	476 (%)
Share of the measurement sites in percentage	≤10.0 mg/l	45.5	40.3
	>10.0–25.0 mg/l	23.1	23.5
	>25.0–37.5 mg/l	14.9	15.3
	>37.5–50.0 mg/l	8.6	12.0
	>50 mg/l	7.8	8.8

5.4 *Success Story Chemistry—Advantages and Disadvantages*

Municipal wastewater treatment achieves a high standard and the P and N loading is known to be a challenge and, at the European level, both of these are in the process of being brought better under control. With the increase of the population, life expectancy and the average age and with the demographic development up to a higher life expectancy, the consumption and use of pharmaceuticals are nevertheless increasing. Every statutory insured person in Germany in 2015 consumed ca. 1.56

defined daily dose (DDD) per day of prescription drugs. Since 2009, this value has increased annually by 2.6% [2].

With this, the drugs belong to the trace substances, which ultimately get into the bodies of water via the wastewater treatment plants and lead to environmental loading. However, not only the use of pharmaceuticals has increased heavily. The increase of other, varied trace substances in wastewater represents a growing problem, for example from detergents and cleaning agents or from the "arming" of textiles against fire, sweat and water.

Historical reasons for the rise of anthropogenic emissions are the increasing industrialisation, the increasing motorisation of inhabitants and an increasing standard of life including eating habits and requirement for warmth.

How complex the subject of the emission of substances has become in the meantime is shown by the drastic rise in the worldwide production of chemicals from 1 mill. tonnes in 1930, 300 mill. tonnes in 1980 [13] to 500 mill. tonnes in 2,000 (+500%). Adaptation strategies for the protection of the environment can barely keep pace with the increase in the number of different chemical compounds, which are commercially synthesised—up to 2006 in total over 100,000 different substances. From 2006, the statistic counts "product" instead of "substance." Through this, also in the case of chemicals, a trend updating can no longer take place immediately. The material diversity within products has also increased massively, thus, for example, a hair shampoo can already contain more than 100 substances. The substances are registered in databases, which had in total 106,211 entries up to 2008. The European Inventory of Existing Commercial Chemical Substances (EINECS) is the directory of more than 100,000 substances, which between 01.01.1971 and 18.09.1981 were on the EU market. The European List of Notified Chemical Substances (ELINCS) is the directory of the ca. 3,800 chemicals, which, between 19.09.1981 and 01.06.2008 have been registered with European authorities pursuant to the national chemical laws. Since 01.06.2008, a further 20,986 substances have been recorded under REACH (Status: 30.06.2018). At the end of 2012, over 70 million chemical compounds were known and registered with the Chemical Abstracts Service (www.cas.org). From these, over 100,000 were synthesised for commercial purposes. In the EU ca. 30,000 chemicals, each with more than 1 t/a, were produced or imported; the large majority of these are organic chemicals. From these some 1,100 so-called "High Production Volume Chemicals" (HPVC have an annual production (ECH 2019)) of respectively over 1,000 tonnes.

6 Do Adaptation Measures Increase Vulnerability?

Anthropogenic adaptation measures mask natural transformation and change processes. Management measures are admittedly positive and effective at the moment, however, they can reduce perceptions and readiness for additional adjustments, which will be necessary for the long term.

The stability obtained in the water supply (through long-distance water supply or storage infrastructures), for example, shows itself to be a loss in resilience capacity, as the intensification of the dryness situation is barely recognised and capacities of adaptation measures (i.e. the supply or storage capacities) as remedial measure have already been exhausted. Local water availability can no longer be directly experienced as they have been in the 1950s, although the pressures on the water resources have soared due to population growth and industrialisation—including agriculture, and not the least Climate Change. Therefore, the awareness of the necessity of saving water is just not present in the population. A permanent collapse of the existing systems is unlikely; evasive movements towards improved, because more sustainable systems are pursued with less vigour and are more difficult to implement. A certain *rebound* effect ensues, since mitigation measures already in place for the water delivery make adaptation measures, for example in consumption, appear less urgent. These days, only in rare individual cases a supply via tank trucks has to take place, which then is interpreted rather as an organisation failure than (what it really is) an expression of a momentary, real and natural, shortage situation. If current adaptation measures are understood only as "compensation for existing site weaknesses [10]", then they do not solve the problem of water shortage in principle, but rather tend towards generating new demand and postpone a sustainable solution further into the future. Above all, the groundwater has a long memory. A current overuse of the groundwater can only be rebalanced slowly through future adjustments.

These paradoxes are also displayed with flood protection. Through flood protection measures water is in part channelled off quicker and so the flooding danger can be aggravated at other locations. Due to a channelling by diking, the natural process of storage and groundwater recharge through filtration is hardly taking place. On the other hand, the demand for further flood protection increases, due to the perceived security status in the settlement and the expansion of infrastructure qualities in former flood plains and endangered areas. Climate Change and the impacts of higher surface runoff induced by land usage changes (settlement, agriculture, woods) exacerbate the problem additionally. Public discussions, e.g. on the flood polder project, show on the other hand, that with every further adaptation measure acceptance is increasingly difficult to achieve. A sustainable approach to flood risk requires a further social debate on the subject by raising awareness of the risks.

A glance at the advancing Climate Change shows that the previous successful adaptation strategies of water management in many cases hinder the low threshold effects of Climate Change from being directly experienced. The lack of ability to experience small events thanks to successful water management measures can paradoxically lower the social resilience towards extremes simultaneously, as more values become established in their protection. Especially with extremes, which exceed the degree of current protection, have to be reckoned with more frequently in the future due to Climate Change. In addition, the resilience has also reduced where the adaptation was not sufficient. There is a lack of acceptance for adaptation measures in the areas in which the interaction of the various impacts in the environment is too complex in order to make them capable of being experienced precisely.

What we urge today for the future is to adjust ourselves to Climate Change and to take more account of the impacts and inter-relationships of the ecosystems in our activities again. The pressure on the systems is not visible or perceptible to the individual. In fact adaptation measures designed to increase the anthropogenic resilience to the effects of the environment on humans, shape our today's awareness of the environment. Human interventions over-shadow natural processes with deliberate effects, but also with undesirable side effects that demand renewed adaptation. The system has become too unstable to be able to do without human intervention. Regulating interventions are necessary in order to curb the effects of nature and humans on society. Adaptive water management and a discussion on environmental effects of a global change that has so far been decoupled from it should be brought together.

7 Beyond Bavaria: Inclusive Thinking

The self-conception of humans in dealing with nature continues to develop significantly. The crisis diagnosis of the Anthropocene promotes a new way of thinking about nature. System transformation with the aim of climate neutrality requires an understanding of the system. This is provided by data and their interpretation. Notable is, however, that if humankind continues to affect natural processes and dynamics decisively, nature can actually no longer be separated from human culture. Nature becomes cohabitant on the Earth. The radius of mindfulness of humans extends to (quasi-intercultural) interaction with nature. How hard it can be to understand other cultures, we learn by the mutually disruptive effects of the current migration processes. The level of consideration becomes the global one, because even the material Anthropocene has global dimensions. Emissions of substances experience a ubiquitous propagation, be it natural mercury depositions or anthropogenic plastic or chemical deposits. With the previous worldwide production of plastic of 8.3 billion tons one could pack the whole world in 2 mm of plastic, and chemical compounds of the precursors and by-products in plastic production come on top of this. The objective for a stable human-nature relationship must be found more quickly, because the closer the relationship becomes the less we can influence the changes and the pace in change. An example of holistic considerations are the many-faceted indicators of the EU Water Framework Directive, all of which must indicate good status before the water can actually be deemed as good ("one out—all out "). However, due to the complexity of the inter-relationships, there is a risk of a blockade in the environment–human relationship. In nature, everything follows a cycle. Therein lies the opportunity for adaptation; foresight presumed.

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A Discussion on Basic Notions

Patrick Dewilde, Michael von Hauff, Klaus Mainzer, Anastassia M. Makarieva, Mathis Wackernagel, and Peter A. Wilderer

Abstract What do basic notions in systems and ecology mean? Several papers in this book propose specific ways of viewing systems (in particular ecological systems) and offer definitions and notions related to their proposed views. These often very compact "conceptual models" aim at providing a means to understand the behavior and evolution of real-world systems, be they economic, social, or ecological. The way real-world systems are viewed by people and politicians influences considerably how humanity deals with their natural surroundings and how they may decide to act in an ecologically favorable direction, given the fact that humanity's actions obviously have major significance for the global earth's well-being. The proposed conceptual models used by various authors in this book differ considerably from each other, making a discussion of their respective merits and shortcomings very meaningful. Six authors joined in the discussion, proposing, supporting, or criticizing points of view and aiming at clarifying the notions they use, while putting them in perspective. The discussion has been ordered as a question and answers session around the main themes. We hope readers will enjoy the clash of ideas and develop further insights motivated by them.

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1 What Is Meant by a *Complex Ecological System*?

Peter: As defined in the Glossary to Patrick's chapter, a system is "a set of entities having constitutive structural relationships". Thus, an ecological system is characterized by the structural relationships of a multitude of organic elements (microorganisms, plants, animals) forming a bio-community.

Patrick: A system is said to be complex if its evolution is unpredictable due to chaotic behavior. In a system with few state variables, chaotic behavior is due to non-linearities, in particular, the occurrence of bifurcations, "strange" limit cycles, and unpredictability of evolution. However, most ecological systems have a large number of independent agents each with its own state variables, and with a corresponding large number of accidental interactions between them. One very common particular source of complexity in an ecological system is random arrival times of interactions between agents. E.g., pro-creation is the result of such unpredictable interactions.

Mathis: Indeed, Earth is covered by ecosystems, with many layers of complexity: vastly differing time constants, climate zones, and large numbers of loose or tight feedback loops, stretching from quick and local to slow and global, and strong human influence. These ecosystems are also exposed to random events (asteroids, volcanos) and highly predictable patterns (annual seasons), amplifying the complexity of the overall system dynamics. Hence, the opportunity to see complexity is near infinite, given that even simple pendulums with merely two degrees of freedom can produce chaotic movements (e.g., Rott's pendulum). But the trick is to also stay actionable in this nearly overwhelming context. It actually is possible to guide meaningful action even in the context of this enormous complexity, because some aspects of the biosphere are quite basic and straightforward. Ignoring engaging with those opportunities while hiding behind complexity does not serve humanity. It only decreases the likelihood of a sustainable future. For instance, there are some basic quantitative constraints that are true no matter the complexity of the ecological systems. If one entity (the human economy) demands more from the host ecosystems than those ecosystems can renew, this poses a quantitative threat that inevitably undermines the long-term prospects for this entity. It is possible for economic entities to overshoot their supporting ecosystems for some time due to accumulated ecological stocks that can be depleted (or sinks that can be filled), but this level of human demand cannot be sustained. This is where much of the attention needs to be. I recognize and emphasize that getting the quantities right is no guarantee for a sustainable future. Nor does it guarantee avoiding surprises. But for sure, not meeting basic quantitative conditions will undermine the ability of the complex ecological systems to provide for that human sub-system, and undermines its resilience.

2 What *Mechanisms* are at Work in a Complex Ecological System?

Peter: The unique property of ecological systems is the interdependency and interactivity of the various elements. In effect, an ecological system exhibits a functional total, often referred to as "super-organism". The physical and chemical conditions at the respective locations dictate which organisms are present at the time of observation. This means that an ecological system is not static in character but is as dynamic as the environmental conditions are. Moreover, diversity and redundancy of the biocommunity act proactively to sudden and gradually developing perturbations. This reminds me of the adaptive cycle proposed by Walker and Salt (see reference at the end). In summary, an intact ecological system might therefore be addressed as a self-organized sustainable system.

Patrick: A major effect in a complex ecological system is the generalized occurrence of *emergence*. In such a system, new, coherent but complex entities arise that are not covered by the constituting properties of the original system. For example, the fact that a cell reproduces by cell division is not derivable from or contained in the laws of physics or chemistry, although these laws are instrumental in the process (they are necessary for it but not sufficient). As another example, humans use sound to convey meaning, but the meaning a sound has does not derive from its physics. The emergent complex entities obey new laws of their own. They are forming novel complex systems by themselves, utilizing properties of the basic system on which they are grafted (for example, humans form societies with specific state variables and laws, while humans themselves are organisms based on cells, which also have specific state variables and laws. Social science is therefore fundamentally different from cell biology and even more from physics). Often, the time scale of the emergent system is largely different from the original, so that state variables of the emergent system are often slowly varying in terms of quantities from the participating original. It is this effect that produces existential stability or identity to the emergent species or system.

3 What Mechanisms are at Work in *Economic and Societal Systems*?

Michael: One of the most important questions for the future is that of economic growth and environmental protection. How do we bring that together (for example, economic growth versus climate policy). But the politicians do not dare to act, because it is a very complex topic. A second topic is the distribution of income and financial/productive assets. Again, the politicians do not dare to do the right thing.

Patrick: Economic growth is mostly measured purely by tallying financial data, like the gross national product (GNP) of a country or of the world, or the gross domestic product that measures the total income of a country. Talking about the GNP, the issue is: "what does it consist of"? It is supposed to measure the monetarized total of "goods" and "services". The ecological issue with that is that the monetarized value of goods has a much too large component of value obtained from natural resources. This is in a large part due to the fact that these resources (like oil, minerals, water, or even human labor) can too easily be exploited because they are generally much too cheap at the source (a more correct measure would discount exhaustion of natural resources!). The way economic output is measured definitively has to change. Such a redirection (to be done with a whole number of measures to be discussed elsewhere) does not diminish economic activity, it may even be instrumental in increasing GNP and thereby generating more economic growth than what is achieved through conservatively protecting existing, natural resources-based industries. The actions to be taken have to influence both the demand side and the supply side. Demand has to be conditioned by emergent, ecologically sound products (a good example is the recent emergence of Photo Voltaic and Wind Energy), while the supply can be influenced by regulations, taxation, and other protecting measures.

4 What is Meant by *State Variables* of a Complex System?

Peter: According to Walker and Salt, the state of a system is defined by the numerical values of the state variables that constitute the system. Typically, complex systems have a multitude of state variables, but only a few control the performance of the system. As an example, the availability of resources (raw materials, energy, talented employees, etc.) defines the extension and the limits within which an economic system can remain active. As soon as the system gets exposed to certain thresholds, the system loses its identity and integrity.

Patrick: I believe there is often confusion in what is meant by "state variables". The detailed state variables of a large complex system are usually not directly available for control by an emergent actor, only some conditioning factors can be influenced, and then only by proxies. For example, mammals have internal regulatory systems for their body temperature, which they can only influence indirectly, e.g., by avoiding infections. The body temperature is itself a complicated function of the detailed state of the organs that constitute the respective body. When talking about control, always at least two systems have to be considered: a base system on which control is exercised and a controlling agent, which is emergent in most cases (there are also intrinsic control mechanisms, but these are seen to be automatic from the perspective of an outside controller), and has its own state variables. That only a few variables can control the performance of a system is largely incorrect: it is the emergent controlling agent who is limited and can access only a small collection of potential controlling parameters using a proxy. This is due to the fact that the laws governing the emergent species (its structure and evolution) do not allow direct interference with the laws of the base system.

5 How do Such State Variables *Evolve*?

Peter: We have to differentiate between sudden and slowly developing state variables. A break-down of an economy or the sudden change from a planned to a market economy (see East Germany after the political change) generates a dramatic threshold, and therefore a loss of identity and integrity of the system affected. Slow changes of state variables such as the rise of the sea level in millimeter scales caused by global warming are not readily visible to the agents in charge. Equally dangerous is the unnoticed descent of the groundwater level caused by over-extraction of water for agricultural irrigation, for instance in Northern India. No precautionary actions have been taken, and this might eventually lead to dramatic consequences.

Patrick: Most "state variables" one considers in Earth's ecology are globalized, often statistical functions of the huge variety of individual state variables of the largely independently acting agents that constitute the system. Such globalized state variables are often conditionals for the existence of an emergent species, and therefore also "slowly varying", because the time scale of the emergence is many orders of magnitude different from the time scale of its base system. E.g., the life span of an organism is many orders of magnitude larger than the time scale of chemical reactions that take place in it. The bodies' temperature is a conditional for the existence of its organs. Control by an emergent species on such global quantities can only be exercised through proxies, i.e., using one or the other mechanism of the base system accessible to the controlling agent and capable of producing the perceived benefit. Such controls may or may not succeed at preserving conditionals essential to the respective species (its resilience). Moreover, emergent species compete with each other for control and may annihilate each other. That some (actually many) variables are slowly varying is often due to inertia or conservation of some quantity (mass, energy, momentum, capital, goods, knowledge...), but it is also true that our global ecological systems are not "closed", so that many quantities are slowly varying thanks to exchange processes in relative equilibrium (e.g., the temperature of the earth, the constitution of the atmosphere or oceans). An emergent species can only be resilient if the control exercised by it on the base system keeps the conditioning quantities within acceptable ranges.

6 What Defines the *Identity of a System*?

Anastassia: While one can argue that the system can retain "identity", without a proper definition of identity, this argument clarifies little. For example, the atoms of gold are identical and they don't age and change in time. On the other hand, identity may refer to a particular trajectory the system follows in space and time. For example, a person retains his or her intellectual identity as long as the brain and memory function normally. If they don't, the intellectual identity is no longer retained, but the genetic identity, fingerprints, etc. are still retained. So what is the identity of a resilient system? Once we define it, in measurable terms, I argue that these characteristics should remain stable and it is this stability that defines the system.

Peter: Identity means the complete agreement of one thing with another thing. Strictly speaking, a thing or in our case a resilient system can only be identical to itself. Strong disturbances might violate the identity of a system. It is no longer the same as before, but might still be resilient but under a different regime, though. Retention of identity has therefore nothing to do with stability.

Patrick: The notion of "identity" and in its wake "resilience" are relative notions. "Identity" requires a differentiation between the subject being identified and its environment. Often even a third instance is involved, namely the agent which identifies. For example, as humans, we recognize the identity of a species within an ecological environment (i.e., both terms "species" and "ecological environment" have been defined and their use is recognized as conformal to our definition). Moreover, identity goes in "layers": we can talk about the "identity of a species" vs. the "identity of a specific member of that species", etc. A dynamic system (as considered by us) is characterized by a number of evolving parameters (its "state") and its identity of a specific system is then, as Anastassia rightly observes, seen as its "trajectory" (in technical terms: the "trace" of its joint state variables). The trace a species leaves behind in the world's evolution (its "identity" according to the definition of "species") is a different thing than the identity of a member of that species. Different types are characterized by different state parameters, different evolution mechanisms, and different time scales: systems that have isomorphic parameters and evolutions belong to the same "species" (this constitutes the species identity of a given member, while the individual trace identifies the member itself). State parameters of a given organism appear, produce traces, and then disappear again. Species have appeared and disappeared on a much larger time scale. Each of these types of systems needs a good amount of resilience just to keep existing, because the environment they live in is perpetually changing, while they want their identity, i.e., the "existence" of their states and its traces, in short, their existence, to remain valid at least for a significant period of time. In the ecological cases we are considering, the thesis is that the resilience of the human species is dependent on the resilience of the system Earth, including the resilience of other species.

7 How Computable are *chaotic* Dynamical Systems?

Klaus: In my paper *From Anthropocene to Artificial Intelligence? Challenges of Machine Learning for Science, Life, and Society*, I considered applications of modern machine learning to ecological dynamical systems. Ecological systems are highly complex, non-linear, and often chaotic. Therefore, the crucial question arises how computable are chaotic dynamical systems in principle. Chaotic dynamical systems model turbulence in ecological systems which are crucial for current debates on climate, population dynamics, and long-term predictions of our planet Earth. Therefore, I supplement some comments and results concerning the computability of dynamical systems from a mathematical and epistemic point of view.

A system is said to be deterministic if its future and past are determined by its present state. An example is classical mechanics with Newton's laws of motion. But, in practice, complex dynamics can often be indistinguishable from chaotic motions. In this case, predictions of the future are practically impossible, although the system is in principle deterministic. A simple case of a deterministic system is a harmonic oscillator with the equation of motion

$$\frac{d^2}{dt^2} + \omega^2 x = 0$$

It is an integrable system with the solution

$$x(t) = x_0 \cos(\omega t + \phi_0),$$

where x_0 and ϕ_0 are the initial conditions. For a given time t, a computer provides a solution $x(t)$ which needs $O(\log t)$ operations. It can be proven that chaotic motion requires a number of $O(\log t)$ operations. Therefore, an integrable system is completely computable and predictable. For a chaotic system, a prediction is not possible, before the future arrives. In the chaotic case, the system is its own best predictor and there is no predictive algorithm with a computational complexity better than $O(\log t)$.

The transition to chaos can be illustrated by the logistic map which was historically introduced in 1837 by Pierre F. Verhulst as mathematical model of demographic growth. It is a mapping of the unit interval [0, 1] on itself which is defined by the first-order difference equation

$$x_{n+1} = ax_n(1 - x_n)$$

with $0 \leq \alpha \leq 4$. The transition from regular to chaotic behavior depends on the growth defined by the parameter α. For $\alpha = 4$, the map is chaotic. If $x_n = \sin^2(\pi y_n)$ is substituted in the difference equation of the logistic map for $\alpha = 4$, one gets

$$\sin^2(\pi y_{n+1}) = \sin^2(2\pi y_n).$$

Therefore, in the case of chaos with $\alpha = 4$, the logistic map is equivalent to

$$y_{n+1} = 2y_n(\text{mod}1)$$

with the analytic solution

$$y_n = 2^n y_0(\text{mod}1).$$

Now, consider a digital representation of y_0 with $y_0 = 0.1101001100010101\cdots$. Each iteration of the map $y_{n+1} = 2y_n(\text{mod}1)$ moves the point in the binary representation one digit to the right and drops the part to the left of the decimal point. In short: One bit of information is erased at each step.

It can now be shown that the solution of $y_{n+1} = 2y_n(\text{mod}1)$ (and that means any prediction) is completely unpredictable. If the first t digits of the initial condition are known, the subsequent digits cannot be determined. The solution for future predictions will depend on ever diminishing details of the initial condition. In general, the set of all possible binary initial conditions corresponds to the set of all possible random sequences of coin tossing (with 0 for head and 1 for tail). Therefore, the development of the system is also random.

These results illustrate the restrictions of even our best supercomputers. In the state of chaos, no prediction is possible in principle. No algorithm could help us to influence and prevent our fate. In other words: In this case, it is too late. Therefore, we must be sensitive to critical signals during the transition of complex dynamical systems. The debate on climate change is a dramatic example.

Patrick: Klaus' examples show that very common systems with only one state variable can show chaotic behavior, i.e., become totally unpredictable after a relatively short time lapse. The more so when the system under consideration consists of a large number of state variables, which, moreover, have interactions that happen at unpredictable times. So: chaos is ubiquitous. Does that mean that predictability disintegrates totally? The answer is: not totally, depending on 1., the complexity of the system (the number of state variables involved), and 2., the time scale. For example, although the laws of gravity of more than three bodies (like our solar system) are known to produce chaotic behavior, we also know that the ephemerides can be predicted orderly in time spans of millenniums, which are short range with respect to the time scale of the universe. Chaos is ubiquitous, but so is emergence, which provides for a (limited) way out of chaos (it was mentioned before by Matthis that not all variables characterizing the state of a system evolve chaotically—in particular quantities that are conserved remain stable). But emergence allows for more. For example, intense traffic (say in Paris) is chaotic, but a taxi driver knows how much time it will take approximately to go from A to B (because he uses information from his peers who are scattered in the jam). This shows emergent control at work in a chaotic situation. Nature is a great performer in generating emergence out of chaos (think about the generation of species). Emergence means that new, often globalized state variables appear for which new laws hold, and which become reliably predictable on a different time scale than the originals. The task of ecological modeling is to properly identify the properties of emergences and utilize those to generate "well-being" of the more comprehensive system, which consists of the original (or base) system and its emergences.

8 What is the Object of *Resilience* and What are the Relevant Parameters?

Peter: The International Resilience Institute at Stockholm defines resilience as the ability of a system to continuously adjust to changing ambient conditions, to absorb disturbances while retaining its basic function, structure, and feedbacks. A system remains in a permanent dynamic state characterized by its identity and integrity. Thus, resilience should not be confused with stability or equilibrium. Resilience is rather a dynamic property. The relevant parameters characterizing a resilient system are the readiness to release, to monitor ambient changes, and to respond by means of reorientation.

Anastassia: I don't quite understand what the term "resilience" adds to the notions of stability and equilibrium, despite your caution. As long as we say that a resilient system retains its "basic function, structure, and feedbacks", this means that these system properties remain stable and do not change. If they do change, then what is it that the system retains?

Patrick: I fully agree with the definition and description given by Peter. A word of caution, however: resilience is often felt as a conservative attitude. For survival of a species, or, better even, for general ecological well-being, much more is needed. In particular creativity and gumption. These notions are not usually covered by the term "resilience". Why not create a "Gumption thinking Institute"?

Anastassia: Regarding creativity and gumption, by far the majority of species in the biosphere survive based on their genetic program alone and do not require any creativity, like birds don't need creativity to build nests. It appears more to be a matter of genetic luck at the moment of evolutionary origin: if the new genome fits adequately to the working ecosystem without disrupting its functioning, the new species will survive. If not, it is not a new species but a defective version of the older one. Our own species, uniquely, mostly bases its functioning on cultural rather than genetic information. We do need "creativity" only in the sense that we need to bring our governing cultural information in accordance with the ecological laws of nature that permit long-term persistence, something all other species already "know" from their genes.

Peter: Correct. Creativity and gumption are properties of Homo Sapiens only. If executed with caution, based on scientifically based knowledge and with respect to ethical norms, creativity and gumption give us the ability to understand changes of parameters, react accordingly, and manage a system in the sense of resilient thinking.

Anastassia: I don't disagree for the disagreement's sake. I honestly don't see what "resilient thinking" means as a general notion. More importantly, I believe that misunderstanding systems for "resilient" (as in the forest example) and mimicking their properties could make things just worse. It won't work. That is why it is important to understand what resilience is if it exists. Take, for example, the idea of "embracing change". Some changes can be embraced, some cannot. Cancer is a change to be fought with, not to be embraced. There are no generalities here.

Patrick: I think that many species of birds show quite a bit of creativity in how they build nests in unusual places! Hence I think that the statements given by Anastassia and Peter on this issue are way too strong. It does not seem true that the genetic program alone defines the behavior of the members of a species or its evolution. The genetic program only contains information on how an adaptive system like mammals and humans (or trees) is created (e.g., the genetic program only contains the necessary triggers for the growing mammal to create all the sorts of cells that will constitute the various organs in the developing fetus). To put it in my terminology: the purely genetic way of viewing things does not take ubiquitous emergence into account. What the brain of a mammal or a human is going to do is not programmed in the genes, only its structure is, and then only in "blue print", while much is left to environmental influences and accidental occurrences (like mutations). That human brains have more potential than those of most species is clear as far as we know, but I would not dare to say that "creativity and gumption are properties of human sapiens only". The notions of "creativity" and "gumption" are human defined with reference to what humans see as their own properties, and hence simply do not apply to other species, although some other species show remarkable properties that one could call great creativity and even gumption. They may survive our species thanks to that!

9 How Does Resilience of a System Differ from *Stability and Equilibrium*?

Peter: Being a civil engineer, I call a structure like a high-rise building or a bridge stable when it demonstrates the ability to withstand a significant disturbance such as a strong wind or an earthquake. In contrast, the resilience of a structure refers to the ability to balance the shock waves triggered by wind forces or an earthquake so that in effect the structure does not fall apart. Therefore, stability is a static, resilience a dynamic notion. The term equilibrium refers to a situation where disturbances are balanced by counter-disturbances as a result of resilience. Likewise, a forest consisting of a monoculture of spruce trees is unstable because it cannot withstand attacks of bark beetles. In contrast, through biodiversity and redundancy, an intact forest ecosystem possesses the means to avoid bark beetle infection of a single tree species. Such systems act as a resilient system with the ultimate effect of stability.

Anastassia: In my perspective, a high-rise building and a bridge likewise balance the waves triggered by wind forces, and the effect is that the structure does not fall apart. The only difference with the resilient system (of which I cannot think a vivid example to be compared to a bridge or building) might be in the amplitude of counterbalances, or the rigidity. If the object is rigid, even a tiny change in the distance between its molecules brings about a huge tension force, which balances the wind force. If the object is less rigid and more elastic, the changes in the location of its parts become macroscopic and visible. But this is a purely quantitative difference, not qualitative. Thus, stability is the resilience of a rigid system, or resilience is the stability of an elastic (flexible) system. This quantitative difference does not have an absolute meaning, one and the same system can be viewed as stable or resilient. Then why use a different word, what does it add? Regarding the forest example, I see it differently. Bark beetles are not a disturbance, they are part of the ecosystem disturbed by clear-cutting and then by artificial replanting which interferes with the natural process of forest succession. Monoculture: this is the disturbance. Bark beetles attack this "wrong biota" to kill it and to initiate normal succession and recovery toward a healthy ecosystem on the place currently occupied by the disturbance. Furthermore, it is not that an intact forest ecosystem somehow "copes" with bark beetles due to redundancy, etc. The intact ecosystem does not have any redundancy. Bark beetles are part of the intact ecosystem, and they just simply never attack it, like normally our immune cells don't attack us. Can you give an example of a real-world resilient ecosystem?

Peter: As said before a real-world ecosystem is resilient as long it demonstrates its ability to continuously adjust to changing ambient conditions, to absorb disturbances while retaining its basic function, structure, and feedbacks. Take global warming as an example of a change of ambient conditions. As long as forestry does not interfere and provides time for adaptation, the forest ecosystem keeps its basic function (e.g., serves as a biotic pump to transport humidity to habitats even in far distances). In contrast, the ecosystem loses its identity when forced into a direction non-compatible with the system's inherent capability of self-organization.

10 What is the Meaning of *Resilience Thinking*?

Peter: Resilience thinking is methods of viewing ecological systems as a reaction to environmental changes by measures of self-regulation. In the case of economic and societal systems, resilience thinking assists agents in operating such system to the benefit of their long-term existence. It appears that resilience thinking is key to sustainability and sustainable development.

Patrick: One should be careful not to restrict the notion of resilience to a single species or emergent entity. Resilience of one emergent system is dependent on the resilience of others. E.g., the resilience of an economic system may be achieved at the expense of the overall resilience of humanity, at least for some time, facilitated by the long-term time scale of controlling variables. The economic exploitation of earth's resources threatens the long-term resilience of the earth's ecology, while it may appear to enhance resilience in a shorter time span. Resilience Thinking must harmonize global and longer time effects of the various interacting entities.

Mathis: In 1972, the tagline of the Stockholm conference, the first large scale UN conference on environment and development, was "Only One Earth". This tagline was a clear recognition that humanity is bound to live within the resource budget of our one planet. Over the years, while Earth science and the ability to track and measure metabolisms and regeneration rates have vastly improved, the conceptual frames to interpret these trends have become ever more fuzzy. One big step in this direction came 15 years later, when *sustainable development* got "defined" by the Brundtland report. The word "defined" is in quotation marks, because that definition is unmeasurable, or untestable, and keeps the idea fuzzy. Whether this was on purpose or not, we can speculate. But it did help avoid conflicts with the "business as usual" trajectory and its proponents, at the cost of inaction. The more recent concepts such as *sustainable growth* or *green growth* are even more confusing, suggesting that there are no trade-offs, and no need for a fundamental adjustment to the physical reality of planetary constraints. Whether the word *resilience* is part of this confusion, we could debate. I have not found many meaningful definitions. The use of the concept feels often like a soft reinterpretation of sustainability, an effort to keep the door wide open so all can participate and no conflicts need to be faced. In fact, if resilience truly means "to absorb disturbances while retaining its basic function", it may not even apply to the current context where the biological metabolism of humanity is so vastly out of scaled compared to the size of its ecological host (i.e., the planet). Humanity's outsized metabolism is driven by The massive use of finite fossil fuel—at a scale that is unlikely replaceable. It might be euphemistic to call the massive overshoot humanity is facing "a disturbance". There have been many books published on resilience, with lack of clarity of how one can observe such "resilience". They tell little about measurable, quantitative conditions that need to be met in order to enable the possibility of resilient outcomes. Few recognize the profound dynamic of global overshoot. My interpretation is that such uses of the resilience concept distract from what seems such an obvious, massive priority: to reduce the human metabolism to a level that Earth's ecosystems can cope with. And again, this reduction of metabolism is not sufficient for a sustainable future, it is merely necessary.

11 Is the *Ball in the Bowl Model* too Simple to Explain Application of Resilience Thinking to Entrepreneurial Systems?

Peter: The Ball in the Bowl model is a metaphor. It is used to explain basic functions and properties of resilience to agents in charge of the operation and maintenance of economic and societal systems. It provides advice but must not be understood as a physical image of real systems. Depth, width, and curvature of the bowl are symbols referring to slow and fast changing variables. The rolling of the ball in case of a perturbation symbolizes the dynamic reactions of the system. The so-called point of attraction should be understood as a symbol of the ideal state of resilience under undisturbed circumstances. The ball does certainly not roll toward this point driven by the power of gravity but by the virtue of the state variables.

Patrick: In my view, the Bowl model is an incorrect rendition of the reality of a complex ecological system consisting of a large number of relatively independent agents. There are just too many degrees of freedom to produce a "bowl". Rather: everything evolves, although there are rapidly and slowly evolving characteristics, mostly depending on the inertia involved. The only way to achieve a modus of control on the evolution is by participating in it. I.e., by creating counteracting measures of the same type that tend to preserve needed conditions for the existence of the species concerned. One has to fight one emergence (like the use of oil for mobility) by another emergence (like what happened with nuclear power), which, in turn, has to be checked by a new to develop emergence (like solar or wind energy), which in turn will have to be checked when new deficiencies appear. There will always be competing emergences, like there are competing species. Long-term resilience is dependent on which emergence wins out.

Mathis: I agree with Patrick. The relative stability of the Holocene that some describe as a Goldilocks situation may come to an end, with more unpredictable climate patterns and shifting ecological productivities. Social stability is also more likely on an expansive trajectory, where "ever more" soothes potential social conflicts, and that trajectory may turn as well. Material contraction, eventually imposed by overshoot dynamics, whether by design or disaster, put more distributional conflicts on societies, adding social instability to the equation. Patrick's "competition of emergences" (possibly turning into a "competition of emergencies") could be a more accurate description of future states than finding another "equilibrium for the ball in the bowl" if humanity fails to proactively manage the overshoot dynamics.

12 Is it Fair to Assume that Persistence to *Outdated Business Models* Leads to Collapse, Chaos, and/or Bankruptcy?

Peter: With reference to an economic system, specifically a company, the adaptive cycle is assumed to keep revolving as long as the managers of the system monitor changes in science, technology, society, and political agendas, release outdated practices when appropriate, and reorient the production modes and sales practices. In case the management neglects ambient change, the company may eventually run into bankruptcy. Its collapse is caused by non-productive chaos.

Patrick: Companies can be destroyed by many effects, in particular non-adaptive management or problematic management decisions (like risky investments in technology), but a major threat to traditional companies in modern times has been emergent technologies like the internet, computers, genetic engineering, social networks, etc. An alert company may take up emergent signals and participate in the emerging growth, but it will usually not do so and expire at its own rigid sticking to its perceived equilibrium. Resilience for a company means to embrace change intelligently. Arie de Geus used to say “Shell does not exist to pump oil, it pumps oil to exist”. Shell will stop existing if it keeps pumping oil!

Mathis: Overshoot, i.e., overuse of ecosystems beyond their regeneration, is possible, but leads inevitably to depletion and weakening of those systems. So, overshoot is possible in the short term, but not forever. How long it is possible depends on the size of the ecosystems’ stocks. Therefore, economies that depend on overshoot and are unwilling to leave the overshoot zone by design will be forced to leave it by disaster (which might well include, or be anticipated by, financial collapse). That’s the mathematically set dynamics of overshoot. Therefore, the answer to the question above is clearly affirmative, if the human economy is in overshoot. And the evidence that humanity is in overshoot seems overwhelming.

13 Does *the Adaptive Cycle* Preflect Reasonably Enough Sustainability Developments of Ecological, Economic, and Societal Systems?

Peter: The adaptive cycle as described above might be considered a process favoring sustainability of the system under consideration. It is a measure of sustainable development. This statement is supported by the following nine statements of Walker and Salt:

A resilient world

- promotes and sustains diversity in all forms;
- embraces and works ecological variability;
- consists of modular components;
- focuses on slow controlling variables associated with thresholds;

– promotes trust, well-developed social networks and leadership;
– places emphasis on learning, experimentation, locally developed and controlled rules (subsidiarity principle);
– embraces change;
– has institutions that include redundancy in their governance structure and a mix of common and private property;
– includes all un-priced ecosystem services in developments and assessments.

Patrick: I agree with the description, although I might formulate it somewhat differently (it sounds a little too conservative to me). I would put more emphasis on gumption and the creation of new emergences that are ecologically beneficial. I believe that is the key to moving economy in an ecologically productive direction: change economic activity in a massive way toward creating ecological well-being. I agree in particular on the importance of "slowly varying variables" as conditions for the systems' existence. The picture sketched in this Walker and Salt statement shows clearly that the "Bowl" model does not apply to the (global) ecological situation.

14 Is it Reasonable to Consider *Panarchy* as an Expression of System Dynamics Characterized by Creative Chaos and Subsequent Controlling Emergence?

Peter: Walker and Salt define *panarchy* as hierarchy of linked adaptive cycles active at different scales: "What happens at one scale can influence or even drive what is happening at other scales". On the other hand, Patrick defines "*emergence* as a property of a system that is not derivable from its structural dynamics, but exercises a controlling influence on its global evolution".

Patrick: The occurrence of emergence in a chaotic system is a fact of System Dynamics. It does not contradict the possibility of a collateral occurrence of panarchy as defined by Walker and Salt. In fact, emergence needs the panarchy. Emergence happens when a new order is created on top of a chaotic or panarchic system, using its evolution mechanisms, but creating its own evolutionary laws (in a non-chaotic system, evolution is fixed: there is no freedom for creative developments out of the blue). In all evolutionary processes, chaos is instrumental in producing the creative freedom potentially leading to novel developments. Computers, the internet, and the smartphone (all three good examples of recent emergences) would never have arisen if people had not been free to explore new possibilities in computing and communication. Resilience is a necessary property of a surviving species, but to ensure its continuing well-being, the species must develop new existential perspectives. Whole Earth Ecology is much more than a necessity for survival. It is an enormous opportunity for human development and well-being.

15 How Can or Should the Physical, Biological, and Engineering Context be Brought Into Economics?

Mathis: This is what I offer as a hypothesis: the lack of physics in modern social theories (including economics, sociology, and political sciences) are a legacy of an unreconciled, denied colonial past. Centers of colonial power operated with resources they were able to get from elsewhere, at low cost, without the consent from “elsewhere”. The development theory did not question that resource appropriation, but framed it as “global trade”. Therefore, a reconciliation with the colonial past may be necessary for the dominant economic and social theories to fully embrace again the physical nature of our individual and collective existence. Such a reconciliation could not just heal but also strengthen economic thinking. It would allow us to recognize that sustainability is a necessary ingredient for securing everybody’s prosperity. It is stunning that the World Economic Forum now identifies 5 of the top 5 most likely global risks as environmental. Yet the same organization’s competitiveness report, and much of the mainstream economic policy thinking largely ignores the significance of environmental trends for their own economies’ long-term success. I have not found a better explanation as one rooted in a still prevalent, unspoken colonial attitude: “I can always get what I need from somewhere else”.

Patrick: One should be careful not to limit the import of so-called natural sciences and engineering into social sciences and economics to “physics”. Biology, system science, engineering, psychology play equally important roles in understanding ecological situations and, a fortiori, the global earth ecology as an integrated system. There is confusion in using the terms “physical reality” and “physics” as equivalent, due to the historical misconception that all phenomena in nature are reducible to effects that can be described by physics. In fact: most of them are not (and will never be). With “complex system science”, an effort was made to overcome the belief in a rigid, deterministic world order ruled by physics. Both economic theory and “physical” science have to take each other’s evolving paradigms into account. Since economics has been a massive contributor to the present ecological situation, the mutual impact of natural sciences and economics becomes crucial for their future as valid vehicles for understanding the earth’s global system and its evolution.

Mathis: yes, physical reality is more than physics. Yet the laws of thermodynamics are fundamental drivers that social theory cannot afford to ignore.

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The Human Health Dimension

Genetics, Neurostimulation, and Robotics: Implications for the Developing Child

Ingo Borggraefe

Abstract Progresses in molecular genetics have improved the diagnostic yield of severe neurodevelopmental disorders in childhood as neuromuscular diseases, epilepsy, and movement disorders. Consequently, for some disorders, a personalized therapy is now available ameliorating the genetic defect even in previously devastating diseases. For example, intrathecal anti-sense nucleotide therapy is now available for patients with spinal muscle atrophy. Early intervention is even proposed in asymptomatic carriers of proven detrimental mutations of the responsible gene, SMN-1. The latter case is now further addressed by the intervention of a neonatal pilot screening program for SMA in Bavaria. Furthermore, gene therapy approaches for this disease have currently been approved by the U.S. Food and Drug Administration (FDA). Other interventions as deep brain stimulation and robotic assisted rehabilitation are increasingly used to improve motor functions in children with movement disorders. However, all mentioned approaches bear high costs and address new challenges for public and private health services. Fortunately, there is increasing awareness of rare diseases in childhood prompting more research in order to find personalized therapy approaches in these diseases.

Keywords Antisense oligonucleotides · Gene therapy · Next generation sequencing · Deep brain stimulation · Robotics · Rare diseases

1 Genetics

Progresses in molecular genetics have improved the diagnostic yield of severe neurodevelopmental disorders in childhood as neuromuscular diseases, epilepsy, and movement disorders [6, 8, 14]. Consequently, for some disorders, a personalized therapy is now available ameliorating the genetic defect even in previously devastating diseases. For example, intrathecal anti-sense nucleotide therapy is now available for patients with spinal muscle atrophy [5]. Early intervention is even proposed

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in asymptomatic carriers of proven detrimental mutations of the responsible gene, SMN-1. The latter case is now further addressed by the intervention of a neonatal pilot screening program for SMA in Bavaria. Furthermore, gene therapy approaches for this disease have currently been approved by the U.S. Food and Drug Administration (FDA). These new and innovative therapies prompted a public discussion due to the high costs for both types of therapies [12]. The costs for gene therapy for SMA are about 2 Mio. US$, and thus comprises the most expensive drug ever approved. Nevertheless, an independent research institute defined the costs of the drug recently at “the upper limit of what seems to be justified and cost effective” [7]. Nevertheless, it is difficult to determine the real monetary value of a medication. Companies take high costs for development, admission, and merchandizing in account for pricing. Critics may claim that the price of a certain medication is also influenced by the impact of the medication itself (i.e., a medication, which “heals” a devastating disease as gene therapy in SMA, might trigger higher prices than other medications for symptom relief). Thus, the high demand for these medications will most likely enforce high pricing as it follows the economic concept of demand and offer. Taken together, these examples show that the cure of rare diseases is a matter of money and that release of new and very expensive drugs is likely to gain public attention in future and will be questioned beside the matter of effectiveness by issues of cost-effectiveness. Pharmaceutical companies should acknowledge that the price of a medication should more likely be related to real and reproducible costs related to development, admission, and merchandizing of the medication rather than to economic concepts of demand and offer in order to make a feasible pricing, which can be covered by national health programs.

For other neurological disorders with common manifestations in childhood as epilepsy, a wide range of genetic defects can be detected. Genes putatively causing epilepsy comprise a plethora of different functions within the CNS. Impairment of ion currents, distortion of cortical development, and enzyme deficiencies are some examples of genetic causes of epilepsy (Fig. 1). However, development of new treatment approaches is more difficult to achieve as compared to neuromuscular disorders as the brain comprises a sophisticated network of interactions and plasticity which evolves within the developing brain not only in utero but also during infancy and childhood. Thus, interfering with genetic causes of epilepsy will probably mean inventing any causal treatment approaches as early as possible in order to avoid false network programming in these cases. In addition, the target cells for therapy are more sophisticated to reach compared to other diseases: in some genetic epilepsies, a distinct neuronal cell type is mainly responsible for the resulting phenotype. Regarding the wide range of different neuron populations within the human brain, it will be a challenge to address different kinds of cell types for targeted therapeutical interventions such as gene therapy or application of anti-sense oligonucleotides.

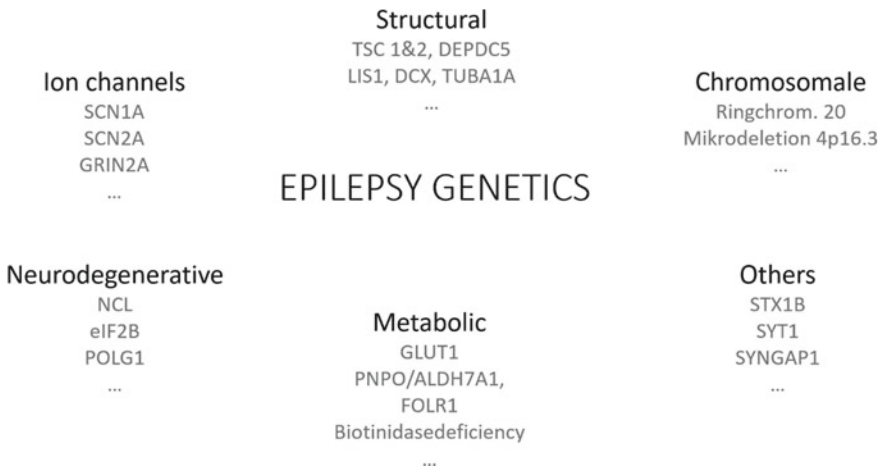

Fig. 1 The figure depicts only some selected causes of genetic epilepsies, which in total comprise a group of hundreds of different disorders

2 Neurostimulation

Neurostimulation is an effective therapeutic approach in some neurological disorders starting in childhood as movement disorders and epilepsy.

Deep brain stimulation is effective in patients with severe generalized dystonia [2, 9]. As a consequence of improved genetic testing, it could be unraveled that some genetic disorders (i.e., DYT-1 and KMT2B) are more likely to be responsive to deep brain stimulation than others closing the circle to what has been mentioned within the previous paragraph [3, 15]. DBS of the internal *globus pallidus* in severe dystonic movement disorders leads to significant reduction of motor impairment and increase in daily participation. However, besides even positive results of motor improvement over years, some patients report behavioral and mood disturbances during long-term stimulation.

Stimulation of the left vagal nerve may lead to seizure reduction in severe epilepsy syndromes [13]. Although the mechanism of action is not clearly understood, manipulation of thalamic networks is thought to contribute to this effect. The effect size is reasonable in some patients though seizure freedom can only be rarely reached. Thus, physicians have to cautiously discuss with the patients the expectations of such a way of stimulation, as expectation to the effect of the procedure might be too high.

3 Robotics

Task-specific body weight-supported treadmill therapy enabled by a robotic gait orthosis improves walking performance in children with central gait impairment [3, 10, 11]. Modulation of spinal networks and improvement of muscle energy consumption are thought to contribute to this effect. Robotic assisted treadmill therapy enabled by a driven gait orthosis (DGO) in adults has been established and shown significant improvements in spinal cord injured patients and stroke individuals. A pediatric DGO has recently been developed and reveals significant improvements in gait speed and endurance in both short- and long-term surveys. Thus, the introduction of robotic medicine in pediatric movement disorders contributes to regain of motor function in children with central gait impairment [1, 4]. These positive results are contrasted by the high costs for a robotic driven gait orthosis making it only available in certain specialized centers.

4 Conclusions

The scope of this report is to reflect the recent advances in medical interventions for children with neurological disorders on the one side. On the other side, the costs of some of these new interventions seem to have reached a tolerable upper limit, which is a matter of a public debate and critics. We believe that this discussion is very fruitful and helpful for patients with these rare diseases to find and approve new therapeutic targets, as both the public and pharmaceutical companies have neglected them for decades. These new approaches give hope to significantly decrease the burden of previously devastating diseases in future.

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The Smartphone. Digital Reverse Transcriptase of Child Development. The New Inner World of the Outer World of the Inner World

Florian Heinen

> *593 A major cause of philosophical malady—one-sided diet: you feed your thinking with only one kind of examples.*
> —Ludwig Wittgenstein, Philosophische Untersuchungen, 1953

Abstract The Smartphone, the Digital Reverse Transcriptase of child development in the beginning of the twenty-first century is transferred to a discourse of understanding seen as fundamental bio-philosophical thinking dealing with ongoing rapid worldwide changes. The available (and even for toddlers simple to use) digital, and especially smart phone technology, is already measurably influencing children's pre-lingual brain and hand motor skills. It seems that human brain and smart phone are mutually influencing their individual development in an almost co-evolutionary sense. Therefore, both technological development and medical research require accompanying philosophical-ethical considerations of how these modified brain activity eventually influences a child's (and later adult's) perception of itself and the connection to its surrounding environment.

Keywords Digitalization · Child development · Smart phone · Physiological fitting · Hand motor function

1 Introduction

We can understand the world only in the context of human development, not without, not against development. Development is childhood. Development and childhood are being neglected in Philosophy so far, not included in our thinking, not included in our view of the world. The essence of human being, of the human brain: An inner world of an outer world developmentally bridged by pre-lingual hand motor function.

This fitting of pre-lingual human hand motor activity and technically simplified availability is new, but matches physiologically the development of the child's brain

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and hand motor skills, also in the sense of abstract and at the same time biologic-mental grasping. In consequence, this fitting has a fascination, distribution, and dynamic that is ‘fitting’ with all early as well as late developmental phases of man, especially children and adolescents. This fitting is perceived as socially irreversible. It could have the potential to define newly the directions that individual developments may take, not (yet) foreseeable, not unidirectional. This fitting gave rise to a quantum leap in possibilities and in turn, to a new evolutionary step of adaptation. Unquestionably, positive constructive possibilities as well as negative destructive possibilities are conceivable. There is a high priority for further understanding and drawing the right conclusions from the ‘smartphone phenomenon.’ We are only at the beginning.

2 The Outer World Appears Clear-Cut

Since Steve Jobs introduced the iPhone in 2007, the smartphone has become an unprecedented success story within an unmatched short time. Indeed, the smartphone became ‘viral,’ spread out, everywhere. It transformed a whole corporation (Apple), rescued it, and made it to the most valuable business in the world—philosophically irrelevant—led to new industries that are typically networking globally—philosophically already a bit more relevant—and as a tangible object always at hand, it has globally changed every day’s world—indeed relevant.

Using the smartphone, more or less ‘everyone’ in nearly ‘every’ culture is able to communicate, mirror, photograph, film, experience, attend to, and design nearly ‘everything.’

The smartphone functions globally viral, in the countryside of East Africa as well as in the financial districts of New York, London, or Hong Kong, in the East and West just as well as in the North and South.

This development in its unparalleled innovation provokes new questions due to a newly conceived interaction of the human hand, technical device, human brain, and transfer of knowledge.

Here, we are considering the question, whether and at which point child development in its specifically human course, its biological complexity, its healthy variable normality, and its underlying natural principles could provide an important key to our understanding of this technology that we no longer perceive as new because it is already so well embedded in everyday life. We concern ourselves with this question, because we are convinced that this ‘fitting of man and smartphone,’ this obvious phenomenon of ‘fitting together,’ is our current social reality and that we should strive for a better understanding of this phenomenon, regardless how society might judge this phenomenon, approval, critic and rejection, and quite independent of the powerful ‘attention value’ that presents a new gold mine for seemingly unlimited commercial exploitation.

3 The Inner World is Not So Clear

Why is the smartphone so attractive for all age groups, why obviously for all people independent of the world region, type of government, or religion? Why has it sustained unbroken attraction? Why are there no signs of a slowing down in attention and of wearing off in fascination with the smartphone?

Considering this background, it is clear that there should be intensive discussion regarding potential risks and undesirable side effects of the smartphone for children and adolescents. However, we decided not to enter into this discussion here at this stage. Not because we are afraid of misunderstandings, inappropriate approval or rejection, but rather we feel it necessary to first understand the biological, physiological 'fitting' phenomenon before turning our attention to developing an 'educational fitting.'

The (unclarified) inner world of a (seemingly) clear outer world of the smartphone therefore requires an excursion and discourse on the fundamentals of child development, which we present below in the form of theses. We hope our theses will provoke a thought process that gives rise to antitheses and syntheses, which in turn may again become theses, ultimately improving our understanding.[1]

4 Discourse on Childhood and Smartphone, Presented in 36 Theses

The development of the child may be described as 'shaping of the inner world in direct relation to the changing outer world' involving the biological age-related and constituent perception and reaction principles applicable to the individual inner world [1].

The inner world of the outer world reflects the mirror-inverted relationship with the outside world, with its own dynamics, potential, and a relatively long time of decided child development, continually and flexibly pursued for a life-long human development and change.

The development of the child is neurobiological sculpturing and neurobiologically sculptured—not simply additive—plasticity of the human brain [2].

In the child's early development, understanding is principally pre-lingual—with emphasis on pre-lingual hand motor function.

Intentional pointing with the index finger is a necessary milestone in the child's development, comparable to free walking, and both are a *conditio sine qua non* in the context of health.

[1] Cf. the dialectic approach formulated by Plato, further developed by the Plato-Augustine intellectual arc into the Christian middle age philosophy and the German philosophy of idealism by Fichte, Schelling, and Hegel.

Hand motor skills represent one of the most human aspects of voluntary motor function. They are especially closely associated with cortical activity of the brain and when considering the whole evolution ‘exclusively human’ [3, 4].

Hand motor function between thumb (D1) and index finger (D2), such as the thumb–index pincer grip, biologically achieves the fastest conduction times (cortico-spino-muscular) and the most direct (monosynaptic) spinal connections between brain and periphery.

Hand motor function is represented within the motor cortex with cortical pyramidal cells embedded in central neuronal networks: Layers 2 and 3 interneurons and Layer 5 first motor neurons. L2 and L3 neurons perform, besides the known regulatory effect by the cell soma, also axonal excitation and inhibition, exclusively attributable to the human cortex.

Hand motor function with emphasis on ‘pointing with the index finger’ and on the radial pincers grip (between thumb and index finger) shows a system-physiological early structural basic maturity of the brain (assessed with the already present ‘adult like’ characteristics during the 1–3 years of life), as well as years later available functional ‘adult-like’ performance maturity (assessed with the ‘adult-like’ characteristics during the 10–16 year of life).

For hand motor function applies: conduction proceeds skill [5–11].

We may consider hand motor function paradigmatically as the development of the inner world of the brain in response to the primarily egocentric outer world ‘hand’ that secondarily is grasping onto the next, increasingly allocentric outer world, the contemporary world.

Considering and accepting that hand motor skills play a paradigmatic role in special aspects of child development, learning, cognition, and abstraction—and in the fitting of brain, hand motor function and smartphone that bring about cultural changes—it would be a mistake to reason that pathologic development with pathologic or absent hand motor function would make the developmental process as such impossible. Development is always possible, also with existing disabilities, also with impaired hand motor function (which may have various causes such as disease, syndrome, or traumatic loss. These are exactly the type of patients that form part of the author’s clinical routine as a developmental and child neurologist). This development is possible because of the child’s basic, naturally existing ‘inner direction and unfolding,’ which finds alternative ways and surprises with variability, plasticity, and creative compensation. By no means, of course, can human development be reduced to hand motor function alone. However, development involves the hand and its function as a very fundamental human tool.

This is new: between inner world and outer world, we say since 2007, a new all-in-one go-between world or all-in-one new world or all-in-one handheld, the smartphone, is squeezing in.

This new world is a kind of intermediate world in the form of ‘physically lying in the palm of the hand’ and a non-physical ‘unlimited availability’ of plenty if not ‘everything’ (including information, music, social networks, and orientation in space).

This type of new world—all-in-one—in the hand and thus in the physiological world of the growing child, is the smartphone.

The smartphone is an irreversible reality also in childhood, also in the developing brain.

Using the smartphone means digital processes: ‘everything is available’ (in digital format).

As the smartphone involves manual handling, pointing, swiping, drop and drag, or pre-lingual use, it may be considered as a kind of digital reverse transcriptase of child development and culture. That is a knowledge or information device that not only builds up—by unidirectional adding—on increasing linguistic competence, but with its haptic (innovation iPhone) and with its increasing accessibility by voice (and/or face/eye interaction) introduces and allows bi-directionality exactly where previously only unidirectional usage—towards an ever more complex language—was possible.

First, the smartphone accomplishes by convergence the pre-lingual simplification ‘on the way to pointing,’ but then it also achieves by divergence a simplification ‘towards language,’ ‘towards voice control,’ and ‘towards face/eye control.’

Using the smartphone means digital procedures: From the moment in childhood development when the child begins to use its hands, the child will be able to digitally enter an intermediate world, access it by pointing/touching, change it, and monitor it.

However, it also means that the child itself becomes digitally socially commensurable, or is made to be so, or is traceable. The child leaves the un-reflected trace of a child’s interests and playful activities, constituting for the first time an unprotected and highly vulnerable field of human behavior and condition outside the protected family environment to a powerful industry.

Using the smartphone means ‘a digital approach to the multifaceted world’: Relating to the hand, using the hand, using the human-specific grasp, and pointing functions in their intuitive pre-lingual purpose (including swiping, dragging for enlarging or reducing, and spreading).

The above considerations suggest an evolutionary–revolutionary fitting of human brain and smartphone, a fitting at several different levels such as visual, acoustic, haptic-sensory, motoric, cognitive, emotional, etc.

The fitting of brain and smartphone (also) includes space and time dimensions.

While the space dimension with its ‘lying in the hand’ micro dimension would seem less critical, the time dimension with its quickly accumulating time also in the sense of consuming is considered a critical parameter.

We are dealing here with a biological–technical fitting and, through this form of pointing, with a new discovery—a product invention (by Steve Jobs) that is changing the world.

This fitting explains the potency when it comes to the globally ubiquitous presence and the individuality.

The accuracy of the fitting regarding the globally ubiquitous presence and the individuality is fascinating in itself.

This fitting allows to critically drawing an analogy to the fitting of alcohol and human brain.

There is fascination for the inner world of the brain as well as for the outer world, such as the society, parents, teachers, politics, and medicine.

Above considerations show that diametrically opposing arguments can be offered for either positive aspects and approval or negative dangers and rejection.

The factor 'development of the brain' and the factor 'development of the hand' and the connective factor 'technical development of a hand-held smartphone' have to be studied newly and more profoundly.

The illustrated complexity needs to be simplified. However, we do not yet understand enough to suggest an effective approach to simplification.

For setting up plausible rules for children and adolescents, it will be necessary though to simplify our understanding and the rules to match the truly active and powerful simplification level of the smartphone.

Basic supportive and protective rules as well as those specifically relating to areas such as medicine, media, family, and school should be developed.

Network strength of the smartphone: This term stands for the smartphone's omnipresence and its powerful possibilities to access readily information and to form and participate in social networks—implying both chances and risks. Such general network strength should be countered with a network strength specifically based on child and adolescent medicine, psychiatry, and educational sciences. All these disciplines should be well prepared with resources, coordinating, differentiating, not dramatizing or catastrophizing. Such efforts should emerge from pediatrics and developmental neurology. The self-proclaimed pseudo-pediatricians and global advisors—painting a dramatic picture but, in fact, only representing themselves—are the opposite of helpful in this discourse.

We are currently in a situation where the Goliath smartphone is progressing in big steps, and we are trying to confront this Goliath with a hardly prepared, not to say limping, David pediatrics.

5 Conclusions

We may consider the smartphone as a new in-between world or as a kind of digital reverse transcriptase of child development and culture.

The new smartphone world is a palmar all-in-one handheld device that makes everything available everywhere, preferably visually, factually, manually. This all-in-one handheld device allows for the first time during evolution such an early access to 'everything.' Access takes place 'in-the-hand' and thus interconnects the 'exclusively human sculpturing hand motor function in the brain' with an 'always immediate availability.'

The term digital has here a threefold connotation: (1) digitalized technical availability, (2) digital (concerning hand and fingers, Latin: *digitus*, the finger) human-specific motor control, and (3) digital reverse transcriptase. Control of hand motor function between thumb and index finger in essence constitutes evolutionary the most human motor function of the hand, closest to brain and self. Image control, knowledge management, and visual control are thereby linked with hand motor function, while at the same time speeded up. Knowledge management is no longer exclusively tied to rhythm, speed, and understanding of the first written and then read words and language, something that is being attained relatively late in the development of the child and is organized in an additive, linear manner. Instead, knowledge management is linked with the relatively early developing pre-lingual motor activities such as pointing, swiping, spreading, and drag and drop, and thus is pre-additive, not linear, and concurrent.

This fitting of pre-lingual human hand motor activity and technically simplified availability is new, but matches physiologically the development of the child's brain and hand motor skills, also in the sense of abstract and at the same time biologic-mental grasping. In consequence, this fitting has a fascination, distribution, and dynamic that is 'fitting' with all early as well as late developmental phases of man, especially children and adolescents. This fitting is perceived as socially irreversible. It could have the potential to newly define the directions that individual developments may take, not (yet) foreseeable, not unidirectional. This fitting gave rise to a quantum leap in possibilities and in turn, to a new evolutionary step of adaptation. Unquestionably, positive constructive possibilities as well as negative destructive possibilities are conceivable (explicitly also a destructive plasticity with the risk of addiction).

There is a high priority for further understanding and drawing the right conclusions from the smartphone phenomenon. We are only at the beginning.

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Can Artificial Intelligence Improve Our Health?

Radu Grosu

Abstract Open and adaptive living systems share many of their underlying principles with artificial rational agents. Control theory and artificial intelligence drew and continue drawing, therefore, inspiration form nature. For example, we have shown that a biophysical model of neurons can reduce the size of a lane-keeping neural network by a factor of 100 in autonomous driving. In this paper, I review the main principles of control theory (e.g., how a rational agent uses the states and rewards returned by a plant to learn the actions maximizing its total expected reward), and of artificial intelligence (e.g., feedforward versus recurrent networks, unsupervised, supervised, and reinforcement learning) in an accessible and comprehensive manner. Smart, distributed control and machine learning technologies have currently entered all segments of our civilization (e.g., farming, energy, mobility, city management, and industry) in order to optimize and individualize processes, increase efficiency and security, and reduce the environmental burden. Examples from health care include the detection of novel disease features in medical imaging, prediction of ablation strategies in cardiology, better growth models for improved tumor control, and optimized rescue of victims of traffic accidents.

Keywords Artificial intelligence · Systems theory · Rational agent · Dynamic programming · Health care

1 Living Systems are Open Learning Systems

Health is an indispensable attribute of all living organisms and a healthy biosphere is essential for the survival of mankind. Scientific and technological advances over the past centuries have considerably improved our health. Unfortunately, it achieved this at a great pollution cost that puts at risk the rest of the biosphere [2]. This will inevitably lead to our doom, too. A key question is therefore, if science and

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technology can now also come to our rescue. Can artificial intelligence help in this respect?

Health is intimately related to life. To understand health, we therefore need to first understand life itself. A descriptive definition of life, from a biological point of view is as follows [11].

Life is a characteristic of open systems that preserves and reinforces their existence in a given environment. This characteristic exhibits all or most of the following seven traits: Homeostasis, organization, metabolism, growth, adaptation, response to stimuli, and reproduction.

A disease occurs when any of these traits is damaged, and the purpose of healthcare is to repair, or at least to control the damage. Repair and control can thus only be conceived after a deeper look into the nature of the seven traits above, themselves. They all involve optimal regulation.

Homeostasis is a dynamic internal equilibrium maintained by living organisms to ensure their optimal functioning. Organization is a structuring principle allowing the emergence of complex organisms from cells, the basic units of life. Metabolism is a set of life sustaining chemical reactions optimally converting food to energy or cellular building blocks, and eliminating waste. Growth and reproduction are responsible for cell increase and division, and the ability to produce new organisms. Adaptation is the ability of an organism to change over time in response to a change in its environment. Finally, response to stimuli is the ability of an organism to optimally interact with its environment.

2 Information Processing is at the Core of Living and Artificial Systems

Systems biology [16] studies the emergence of complexity in functional organisms from the point of view of dynamic systems theory. Control theory [3] and artificial intelligence [14] draw inspiration from living organisms, too, with an emphasis on information processing. The latter is at the heart of all the above traits, through the very concept of optimal regulation.

Open systems use information processing in order to learn a dynamic model of their environment, including their own abilities, with the purpose of acting in an optimal fashion to a possibly unbounded sequence of environmental stimuli and rewards, each associated to their previous actions.

Acting in an optimal fashion refers to choosing the actions that maximize the total expected reward over time, also known as the utility of the system. In biology, rewards play a central role [7], and they range from most primitive ones, such as pain, hunger, and pleasure, facilitating survival and reproduction, to more abstract ones, such as promotion, or simply winning a game in sports, facilitating selection. Reward shaping [15] is also a main concern in artificial intelligence and decision theory [1]. The open system, called a rational agent [14], is assumed to possess finitary means, only, and key to such means are learning and memory. This is where most of recent advances in artificial intelligence, in particular in machine learning, happened.

The architecture of a rational agent, together with its environment, is shown in Fig. 1. The physical plant represents the environment to be controlled, for example, one of the seven life traits in biology, or a factory, energy system, or even a car in engineering. The plant has a set of sensors, actuators, and rewards. The actuators control the behavior of the plant, whereas the sensors and rewards provide evidence, or feedback, about the state of the plant and also about the desirability of this state. The main goal of the rational agent is to maximize the total reward $r = \sum_{i=1}^{\infty} \gamma^i r_i$ received from the plant over time, in expectation, where $\gamma \in (0, 1)$ is a discount weighting the importance of future rewards.

As the evidence output by the plant might contain incomplete information about the internal plant state, a state estimator is used first, to compute the most likely state of the plant $P(b|\boldsymbol{e}, \boldsymbol{a})$, also called a belief state, from the past sequence of controller actions $\boldsymbol{a} = a_1 \dots a_n$, and the past sequence of plant evidence $\boldsymbol{e} = e_1 \dots e_n$. For this purpose, the estimator takes advantage of a stochastic model of the plant, consisting of two distributions: the next state and reward probability, given the current state and current action $P(s', r|s, a)$, and the evidence probability, given the current state $P(e|s)$.

The current belief state and the current reward is given to an optimal controller, which computes the current action $a = \pi(b)$, such that the utility $U(b)$ of the agent, that is the rewards it receives over time starting from b, are maximized in expectation. The agent may possess a map, or desired-goals landscape, allowing a planner to compute an optimal path p, that is a sequence of waypoints, or sub goals, which are also given to the optimal controller.

A very important question is how does the rational agent infer the plant model, the current belief state, the optimal action, and the waypoints? In biology, this is achieved through very sophisticated regulatory networks [7], which are either chemical and therefore slow, such as gene regulatory networks, homeostatic regulatory networks, metabolic regulatory networks, and reproduction regulatory networks, or electric

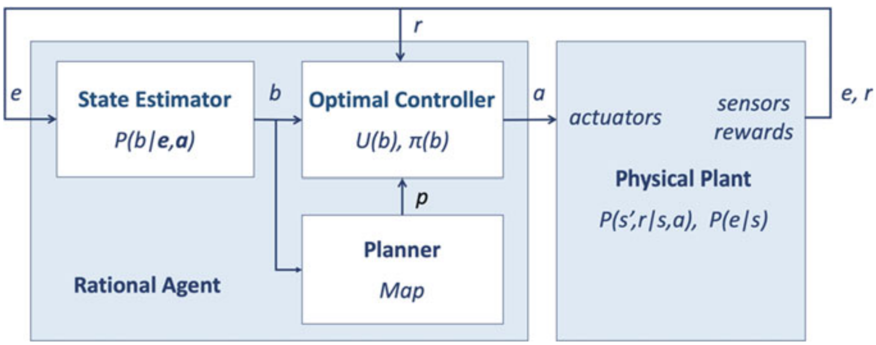

Fig. 1 The architecture of a rational agent together with its environment

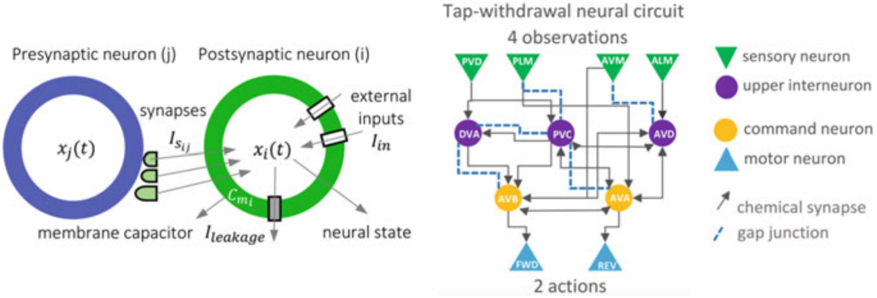

Fig. 2 Simplified architecture of biological neural networks

and therefore fast, such as neural regulatory networks. All these networks possess plasticity, that is, they adapt to environmental changes. In neural regulatory networks [7], the basic information-processing unit is the neuron and its synapses, with which the neuron interacts with the other neurons. A simplified architecture of biological neurons and their associated neural networks is shown in Fig. 2.

Figure 2a shows a biophysical model of biological neurons [7, 9, 17], which focusses solely on the electric interaction between pre- and post-synaptic neurons. Electrically, the fatty membrane of a neuron is a capacitor, and the inside–outside difference of ionic concentrations defines the membrane potentials $x_j\ (t)$, $x_i\ (t)$ of the neurons at time *t,* respectively. The neurons interact with each other through either electric synapses, also called gap junctions, or through chemical synapses, which are either activating or inhibiting. Through each synapse *s* passes a current $I_{sij}(t)$. Through the membrane also passes a passive leakage current $I_{\text{leakage}}(t)$ and possibly an input current $I_{in}(t)$.

Figure 2b shows a simple neural circuit [17] of the C. elegans nematode, the so-called tap withdrawal circuit. The circuit has four sensory neurons, responsive to forward, backward, and middle taps, of the Petri dish containing the nematode; two motor neurons, causing either a forward or a backward movement; three interneurons further processing the inputs; and two command neurons. The neurons are recurrently interconnected through either gap junctions or chemical synapses. Originally, the circuit causes the nematode to make a large forward or backward movement, of the size of the nematode, in case the dish is tapped on the back-side or the front side of the nematode, respectively. In case the dish is tapped close to the middle of the nematode, the nematode decides to move backwards. If, however, repeated taps to the dish do not harm the nematode in any way, the nematode learns that there is no harm, and considerably reduces its movement response.

At TU Wien [10], we developed a biophysical model of neurons and synapses, capturing the above electric description with smooth ordinary differential equations. This model is more complex than artificial neural network models, described below, but it is much more succinct, as each neuron can accomplish more complex tasks.

For example, to get a taste of this succinctness, we were able to learn a lane-keeping controller for an autonomous driving car with only 19 neurons, whereas the corresponding artificial deep neural network learned by our MIT collaborators, required 1900 neurons for the same precision [10]. Both networks were able to drive successfully a car equipped with appropriate sensing and actuation capabilities on the streets of Boston. Owing to its small size, the biophysical network is also explainable [10] and thus certifiable. However, this is not the case for the deep neural network.

3 Principles of Machine Learning

The key property of biological networks, that enables them to learn while interacting with their environment, is the plasticity of synapses, that is, the ability of synapses to change their strength in response to the accumulated rewards, for example, in the form of serotonin [8].

Artificial neural networks [5] take this observation to the limit, by using a model that very remotely resembles biological neurons, only. Each synapse s has an associated weight w_s, which multiplies the value presented by the presynaptic neuron. The neuron itself makes a smoothened, step-like decision, called a sigmoidal output, based on the sum $\sum_{i=1}^{n} w_i x_i - \mu$ of its weighted inputs and its associated bias μ. A network that has at least two hidden layers and sufficient neurons, can approximate to arbitrary precision any nonlinear function. The more hidden layers are available, the easier it is to learn the function, as each layer acts like one parallel step of a sequential computation. Thus, layers decompose the original function in the sequential composition of simpler functions. If the network has more than two layers, it is called a deep neural network [5]. According to the graph structure of the network, one distinguishes between feedforward and recurrent networks. Figure 3a shows a feed forward network [5], that is, a network with no feedback connections.

This network has one input layer x, one output layer y, here with a single neuron, and l hidden layers of neurons. Like biophysical networks, these networks can be trained to accomplish a particular task, such as lane-keeping in autonomous driving. Their drawback is that they tend to be very large, in both terms of depth and width, and the individual role of each neuron is very hard to explain. If a network allows feedback connections, like in biophysical networks, then it is called recurrent [5].

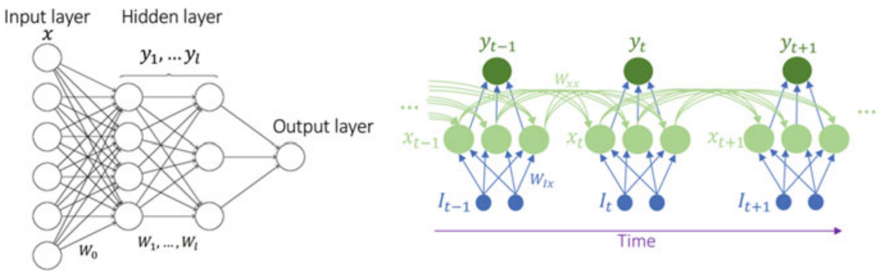

Fig. 3 A feedforward and a recurrent artificial deep neural network

In such cases, the behavior of a network can be explained by its unfolding in time, in a feedforward network, as shown in Fig. 3b. In this unfolding, each slice t computes the output y_t based on the current state x_t. The current state is computed based on the current input I_t and the previous state x_{t-1}. Recurrent networks are especially useful in sequential decision tasks, where the current output, or action, depends on the entire sequence of previous evidence and previous actions. Hence, recurrent neural networks are very well suited for learning the components of a rational agent.

The *learning techniques* are best explained in terms of Fig. 1, giving the architecture of a rational agent. They *can be classified into three categories:* Unsupervised learning, supervised learning, and reinforcement learning. The main goal of unsupervised learning [5] is to uncover the fundamental patterns within the environmental, that is, the plant's evidence.

The basic neural architecture employed for this purpose is a fan-in fan-out feedforward network, called an autoencoder. The fan-in encodes (compresses) the evidence through successively smaller layers of hidden neurons. The fan-out feedforward network decodes (decompresses) the state obtained this way, through successively larger layers of neurons, such that the output state, reproduces the input up to a desired precision. Each neuron of the middle layer, containing the smallest number of neurons, can be understood in this case as a fundamental feature, or pattern of the evidence, as the nonlinear combination of these features is able to accurately reproduce the original evidence. More advanced techniques include variational autoencoders [13] and generative adversarial networks [6]. An example for the use of unsupervised learning is uncovering the main patterns occurring in prostate cancer, for different levels of cancer malignity, as defined by the well-established Gleason score [4].

The main goal of supervised learning [5, 14] is to learn an input–output model, given a set of desired input–output sequences.

For example, given action sequence $\boldsymbol{a} = a_1 \dots a_n$ and evidence sequence $\boldsymbol{e} = e_1 \dots e_n$, the goal is to learn a plant model that produces for same actions an evidence $\hat{\boldsymbol{e}} = \hat{e}_1 \dots \hat{e}_n$, that minimally differs from the plant evidence $\boldsymbol{e}$, according to a given cost function. A very popular cost is $\sum_{i=1}^{n} (e_i - \hat{e}_i)^2/2$. Minimization is achieved by successively updating the synaptic weights of the neural network through backpropagation and stochastic gradient descent, until a local minimum, sufficiently close to the global one, is achieved. Supervised learning is not restricted to plant models. One can also apply it to the optimal controller, if one already has a teacher. This can be a human or a program, producing the proper actions given the current states. An example of supervised learning in medicine is prostate cancer segmentation, where the prostate is delineated by an expert physician within the input image [4]. A further example is classification, where the malignity of the prostate carcinoma is labeled by a physician according to the Gleason score [4]. In this case, one obtains superior results, if supervised learning is combined with unsupervised learning. The latter abstracts the pixels in the original image into very useful lower dimensional features, which considerably simplifies the ulterior classification of the carcinoma's malignity.

Finally, the main aim of reinforcement learning [14, 15] is to learn an input–output model, for example, the optimal controller of a rational agent, solely based on rewards.

While supervised learning cannot learn better models than their teacher can, reinforcement learning can, by discovering new actions on their own. Rewards are the most abstract way of teaching, and they may only occur after many actions. Synaptic weights are learned by maximizing the cumulative expected reward. If a finitary plant model is available and the plant is fully observable, then one may employ dynamic programming in order to solve the Bellman equation [1], defining in a recursive fashion the utility of a rational agent: $U(s) = R(s) + \gamma \max_a \sum_{s'} P(s'|s, a)U(s')$. Note that knowing the model is equivalent to knowing the recursion-unfolding tree of this equation, for every possible action and every possible next state. If the model is not known but it is finitary, one can employ adaptive dynamic programming, to learn the model on-the-fly. If the model is not finitary, one can employ Monte-Carlo execution sampling, where a sample corresponds to one path in the tree, or temporal-differencing, which amounts to executing just one step. In this case, the utility of a state is $U(s) \cong U(s) + \alpha(R(s) + \gamma U\left(s^{'}\right) - U(s))$. The parenthesis contains the prediction error, that is the difference in the utility after and before action a in state s leading to next state s' and reward $R(s)$. The learning rate is tuned with α. In neural networks, the main learning tool is the policy-gradient theorem stating that: one has to update the synaptic weights, proportionally to the sample utility, and to the gradient of the probability of choosing the action actually taken. Learning any kind of sport involves reinforcement learning, and so does the optimal irradiation in prostate carcinoma [4].

4 Applications of Artificial Intelligence

Combining the classic, hypothesis-driven approaches to health care, with the novel, data-driven machine learning techniques, is already unleashing a revolution in health care: *Imaging* mines vast imaging repositories for overlooked disease traits that are thereafter used in better disease classification and control. *Cardiology* is on the brink of creating personalized dynamic heart models that allow to explore the results of various ablation strategies in atrial fibrillation. *Oncology* exploits data-driven techniques to learn better tumor-growth models and develop novel strategies for improved tumor control. *Cities* are learning dynamic models, facilitating optimal first response in case of accidents. This requires traffic, patient, physician, and hospital distributions. However, artificial intelligence technology in health-care is still in its infancy. A better understanding of how to apply it in order to repair or at least control diseases will open—without any doubt—treatment possibilities that we could have never dreamt about today.

Artificial intelligence can also indirectly help to improve our health, by more efficiently regulating our industrial society [12]. This will considerably reduce pollution or human fatalities. For example, artificial intelligence is expected to play a key role in.

Smart mobility with the grand challenge of zero traffic fatalities. Autonomous cars are expected to reduce pollution and accidents through optimal control.

Smart energy with the grand challenge of black-out free electricity. The energy grids will be operated by smart and adaptive controllers.

Smart buildings with the grand challenge of energy-awareness. Deploying a swarm of sensors and actuators will allow for much better monitoring and control.

Industry 4.0 with the grand challenge of on-the-fly production. Digital twins and the industrial Internet of things will revolutionize the way factories work.

Smart farming with the grand challenge of max-yield agriculture. Sophisticated weather prediction and the agricultural Internet will be a game-changer.

In all the above areas, the Internet of things, akin to our body, is going to play a central role. Its swarm of sensors and actuators, like our skin and muscle cells, the fog, like our spinal cord, and the cloud, like our brain, will all employ machine learning technology, in order to enhance their own abilities.

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Allergy and Civilization

Johannes Ring and Heidrun Behrendt

Abstract Allergy is an alteration of immunological reactivity leading to hypersensitivity disease with inflammation of skin and mucous membranes up to life-threatening generalized reactions (anaphylaxis). Allergies have increased in prevalence worldwide to an estimated 20% of the population affected. The reasons for this increase are explained mainly by two hypotheses: (1) decrease of early life immune stimulation ("hygiene hypothesis") and (2) increase of environmental pollutants in the environment ("pollution hypothesis"). The most marked increase in allergy prevalence occurred in the Northern hemisphere in the decades 1960–1990 together with reduction of rural environments and increased traffic exhaust exposure and urbanization. These changes occurred at a slower rate in Eastern European former communist countries leading to the well-known East–West differences in allergy prevalence. Climate change with increasing pollination periods and intrusion of allergenic neophytes additionally contributes to the increased allergy prevalence. Other sequels of climate change like heavy weather events (thunderstorms) lead to exacerbations of asthma by exposure to small respirable allergenic particles and long distance allergen transport. Allergies therefore represent an indirect health outcome parameter of climate change. Psychosocial factors connected with the acceleration of daily life and increasing psychologic stress may also play a role. **Allergieshave been called the "epidemic of the twenty-first century"**. Allergies have been called the "epidemic of the twenty-first century." There is no doubt that apart from genetic susceptibility, civilization-associated environmental factors with the so-called modern lifestyle play a critical role in the development of allergies.

Keywords Allergy · Environment · Civilization · Pollution · Climate change

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Table 1 Most common allergic diseases

Allergic rhinoconjunctivitis ("Hay fever")
Bronchial Asthma
Atopic dermatitis—eczema
Urticaria (nettle rash)
Angioedema (Quincke's edema)
Anaphylaxis ("allergic shock")
Gastroenteritis (food allergy)
Agranulocytosis (and other cytopenias in the blood)
Serum sickness (arthralgia, fever, nephritis)
Allergic contact dermatitis
Exanthematous drug eruptions
Granulomatous reactions

1 Allergy and Allergic Diseases

Allergy is a specific alteration of the immunological reactivity against—mostly harmless—environmental substances leading to hypersensitivity disease [19]. Allergic diseases manifest most commonly at the exterior and interior surfaces of the organism, namely, skin and mucous membranes, being the border of the individual to the environment. After specific exposure from the environment and on the basis of an individual genetic susceptibility, the immune system reacts with induction of inflammation in skin, airways, or gastrointestinal tract. In severe cases, generalized potentially fatal "anaphylactic" reactions can occur. Table 1 enlists the most common allergic diseases (Table 1).

The pathogenic immune reactions leading to allergic disease can be classified according to several pathophysiological pathways involving different immunological cascades. A more recent classification describes six types of non-communicable inflammatory skin reactions on the basis of clinical and dermatohistological patterns, immune reactivity, cytokines involved, and molecular therapeutic targets [5].

Allergies are the most common non-communicable inflammatory diseases and represent a major health problem in most countries of the world [16]. The most common allergies are mediated by immunoglobulin E antibodies on the basis of a Th2-dominant immune reaction.

2 Environmental Factors

Allergic diseases are classical "environmental" diseases. Both elicitors and adjuvant influences originate in the environment either as biogenic or anthropogenic factors [1, 3].

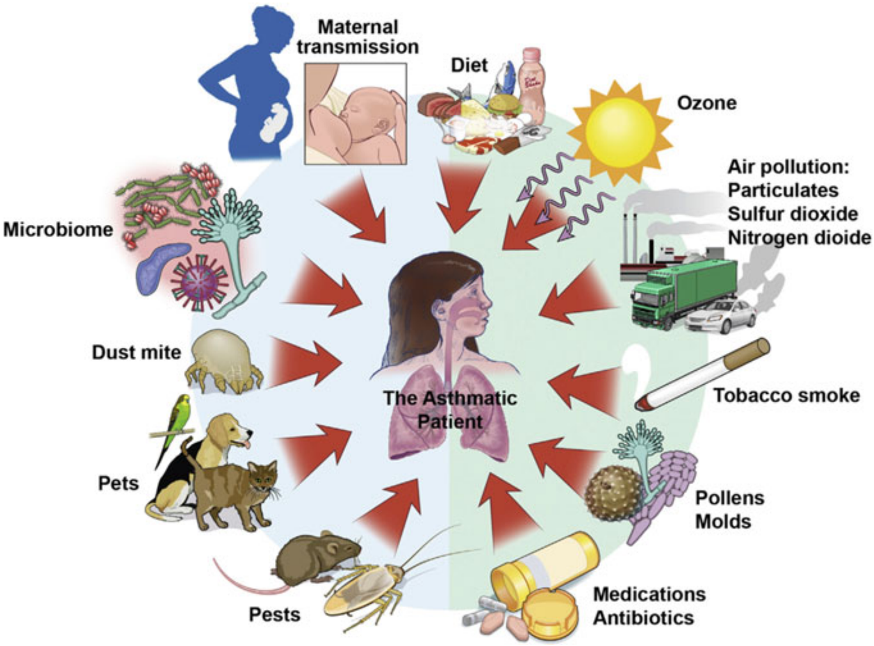

Fig. 1 The exposome concept considers all exposures of an individual in a lifetime, and how those exposures relate to health [21]

Figure 1 shows the most important environmental factors stimulating the immune system and driving allergy after exposure, the so-called "exposome" with single factors enlisted in Tables 1 and 2.

3 Epidemiology of Allergic Diseases

Anecdotal descriptions of allergic diseases can be found in ancient Greek and Chinese medical literature [2], however, there is no doubt that allergies have increased in prevalence predominantly within the last 50 years. Estimates go to prevalence rates of 15–20% for hay fever (allergic rhinoconjunctivits), 5–10% for bronchial asthma, 15–20% for atopic eczema (= atopic dermatitis) in children and 3–5% in adults. The Global Asthma Report [23] describes 339 million affected individuals globally with a special predominance in children and elderly (Fig. 2).

Allergic diseases not only go along with a high degree of individual suffering and impairment in quality of life [20], but also with tremendous socioeconomic costs, especially with regard to allergic contact dermatitis as one of the most common occupational diseases worldwide [17].

Table 2 Environmental factors influencing allergies—The Exposome

Physical
Ionic radiation
Ultraviolet radiation
Mechanical irritation
Particulate matter
Biological
Microbiome, microbes
Allergens (pollen, molds, animal proteins)
Foods
Chemical
Gaseous pollutants (NO_2, SO_2, Ozone)
Solvents, metals, small chemicals
Environmental tobacco smoke
Industrial exhaust
Drugs
Psychosocial
Emotional stress, mental stress
Life events

4 Causes for the Increase in Allergy Prevalence

The most marked increase in prevalence of allergic diseases took place in the Northern hemisphere in the last decades of the twentieth century. After the end of the Second World War, dramatic changes occurred in lifestyle in Western industrial countries together with rapid development of economic growth. This "Western life-style" has been associated with allergies and comprises not only material resources but also psychological factors (Table 3). It includes both outdoor and indoor environment, heating habits, improved hygiene, reduction of parasitic and infectious diseases through vaccination programs as well as reduction of physical exercise and altered dietary habits.

It may be more than coincidence that the first scientific description of an allergic disease, hay fever, was given at the beginning of the nineteenth century in England, the country where modern industrialization began [2]. The first epidemiological investigations studying the phenomenon of allergies started in the 80s of the twentieth century, when a new feeling for "natural environment" rose as sequel of the phenomenon of "dying forests" in Germany. Here, the forest plays a special cultural role in going back to the philosophy of German idealism (Fichte, Schelling, Hegel) and romanticism in the early nineteenth century. It was speculated at that time that the causes were the "acid rain" with sulfur dioxide from big power plants.

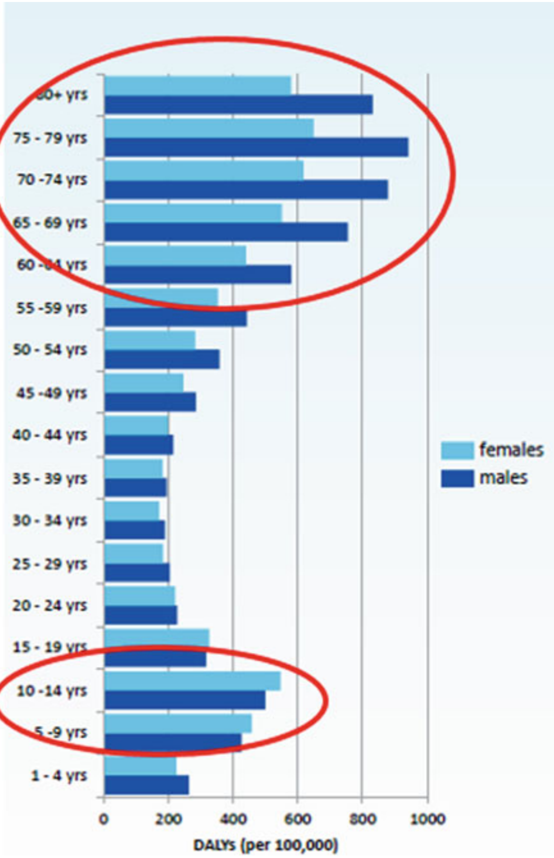

Fig. 2 Prevalence of asthma allergies at the global level in different age groups (*Source* The Global Asthma Report [23])

Similar ideas were then transferred in the attempt to explain the increase in allergies leading to two rather surprising and partly paradoxical hypotheses, each supported by epidemiologic studies:

(1) In a number of studies comparing allergy prevalence between Western and former Eastern German children and adults after German reunification in 1990, lower rates of hay fever and asthma were found in East German and East European children as compared to West Germany and Western countries [24]. These differences were mostly present for airway allergy and not for atopic eczema, they disappeared in children born after 1990. Until today, these differences are still not fully understood. Various studies point to several factors involved as, i.e., different patterns of air pollution and of traffic exhaust exposure, different vaccination programs as well as different heating habits in former East and West Germany [12].

Table 3 Characteristics of Western lifestyle

Material resources
Electricity
Canalization
Development of individual traffic with automobiles
Development and use of nuclear power
Change of architecture with insulation to safe energy
Nutrition with standardized baby formula
Globalization of foods
Increased use of chemicals in daily life
Central heating
Improved hygiene with reduction of parasitic infestation
Vaccination programs with reduction of infectious diseases
Psychosocial characteristics
Wealth
Urbanization
Social isolation (single life)
Acceleration of daily life
Mobility
Profit orientation and "greediness"
Emotional and mental stress
Digitalization?

(2) At the same time, studies from Switzerland, Austria, and Bavaria found that farmer's children were significantly less often affected by allergies than children of other non-farmer inhabitants living in the same area [7, 18]. Although these results are not yet completely understood, it is known that the maximal protective effect of a "farm environment" is provided when the mother has been working in the stable during pregnancy. Therefore, an allergyprotective effect of immune-stimulating substances in the farm environment, possibly of microbiological origin, has been postulated [22]. Earlier studies from Latin America described highly elevated serum levels of immunoglobulin E in Waorani Indians living in the jungle of Equador, where allergies were unknown, however, intestinal parasites were frequent [13].

The Th2-dominant IgE reaction played an evolutionary role in the protection against large intruders such as parasites on skin and mucosal surfaces; but with improved hygiene, the system reacts in the absence of pathogens against harmless substances like pollen with resulting inflammation.

5 Role of Air Pollution

First investigations studying the role of traffic exhaust emissions in the development of allergies came from Japan. The group around Terumasa Miyamoto noted that there was a significant rise in allergic rhinoconjunctivitis against pollen from Japanese cedar in those areas, where there was high traffic together with cedar growth while traffic alone as well as cedar woods alone were not associated with marked hay fever prevalence [14]. In further studies and animal experiments, the group could show that diesel exhaust particles were able to enhance IgE responses to natural allergens from pollen. Since then, it became clear that qualitative differences in air pollution patterns have different effects on allergy development and exacerbation. The classic "smog episodes" of the 1950s in England or in former German Democratic Republic and other East European communist countries—characterized by large dust particles and sulfur dioxide (SO_2) as markers—was associated with bronchitis and pneumonia but not with allergy. In contrast, in highly industrialized modern societies, urban air pollution—characterized by fine and ultrafine particles and nitrogen oxides (NO_x)—is clearly associated with the development of allergies.

6 Modern (Western) Lifestyle

There is no doubt that Western lifestyle is associated with allergies, however, it is not clear which factors or substances are of critical importance at a molecular level. Trying to analyze some factors, one has to go back to the decades after World War II, and see what differences exist between then and the last decade of twentieth century. Some of these factors are part of a changing "civilisation" into a modern society. They include not only material resources like electrification, canalization, industrialization, increase in individual mobility and traffic, development and use of nuclear power, urbanization, energy saving, isolation of buildings, but also increased use of chemicals, central heating, improved hygiene with reduction of parasitic and microbial infections, development of vaccination programs. Altered dietary habits with introduction of standardized baby nutrition, fast food, and availability of a multitude of products from the whole word (globalization) equally have to be considered. Table 3 lists the most important characteristics of modern ("Western") lifestyle also including psychosocial factors. This raises the question whether allergy development might possibly have something to do with a free society.

A number of studies have shown unequivocally that influences from civilization in the sense of Western democratic societies with a strong socioeconomic component are associated with frequent occurrence of allergies. Apart from East–West comparison studies before and after German reunification and studies from alpine farmers in Austria, Switzerland, and Germany, there are studies showing that migrants show lower prevalence rates of allergy in the first generation, but in the second generation, their children acquire allergies in a similar prevalence as the host population [4].

This has been shown in Turkish children in Berlin [8] and similarly in Scandinavian countries. In Australia, the risk for hospital admissions because of severe asthma during thunderstorms was significantly increased in migrant patients born in Australia [10].

In the center of KarKar Island, Papua New Guinea, where there are still original living conditions without foreign influence (houses without fixed fundament, close contact to animals), allergies were practically unknown. In a small town nearby the sea with some contacts to the outside world, measurable prevalence of allergies was found; in villages between mid-island and sea, occasional small prevalence rates of allergies were recorded [9]. Similar findings came from studies in specifically selected, mostly religious, conservative communities with very traditional lifestyle, namely, Amish people in Pennsylvania or anthroposophical families in Stockholm [6, 15].

It must be kept in mind that not only physico-chemical factors characterize a modern society but also psychosocial influences are involved which are difficult to measure. Whealth, urbanization, individualization until social isolation may play a role as well as acceleration of daily life, increased mobility, profit orientation, and "greediness"; they may all give rise to psychologic stress, and thereby influence the development of allergy (see also Table 3).

7 Global Aspects

In the twenty-first century, it has become clear that allergies are not only restricted to "Western" countries or to the Northern hemisphere. Similar increases in allergy prevalence exist in Latin America, Asia, and Africa [16]. However, at the same time, an undoubted influence of Western culture and civilization is spreading upon most countries of the world, not only reflected by use of automobiles, modern communication means, and media, leading to a behavioral setting called "modern life-style."

Most factors from the environment play a role as either modulating factors being protective or acting against allergy development (farmhouse environment, early infections, immune stimulation) or as allergy enhancing factors like pollutants and stress.

The causal eliciting factor in allergy, however, is the allergen of animal or plant origin, which is able to provoke an immunological sensitization in genetically susceptible individuals, and later the allergic disease.

8 Role of Climate Change

In this context, Climate Change is of great concern since both, an increase in allergen exposure through longer pollination periods and alteration in the spectrum of allergens has been observed through global warming as well as alteration of habitats of allergenic plants. Indeed, neophytes like Ambrosia artemisiifolia have become common in some European countries. Among the health effects of Climate Change, not only strong weather events (thunderstorms, flooding, etc.) have to be mentioned with exacerbation of bronchial asthma by exposure to small allergenic particles being released from pollen during thunderstorms [10]. Long distance transport of airborne particles including allergens can be promoted by heavy winds thereby inducing allergic reactions against foreign allergens. Increased human activities in indoor and outdoor environments can lead to the growth of mold, also, being a potential allergy risk. Since 2014, allergies belong to the well-recognized detrimental indirect health effects which are or will be going along with Climate Change scenarios [11].

9 Prevention Strategies

Until the beginning of the new millennium, the common allergy prevention strategies mostly contained recommendations for "allergen avoidance," except breast milk nutrition for infants as active procedure. There has been a change in paradigm with emphasis on active introduction of tolerance in early life. This includes the diversity of foods—after four months breast feeding—and balanced diet procedures like Mediterranean diet, prevention of dysbiosis in the gastrointestinal tract by pre- or probiotics or active induction of tolerance by feeding allergenic proteins, e.g., peanuts. In addition, pet keeping may have protective influences—at least for dogs, while cats still seem to be a too high risk factor for individuals with an atopic predisposition. Sportive activities are also no longer forbidden; obesity also has been recognized as an additional risk factor for the development of allergies.

10 Conclusion

Allergies represent a major health problem in most countries of the world. They have increased in prevalence over the twentieth century to an estimated 20% of the population. Allergies are associated with industrialization and civilization in the sense of Western lifestyle activities; allergic individuals represent a vulnerable group in the society. On the basis of an individual susceptibility, development and exacerbation of allergic diseases depend on the actual exposure to causal or modulation factors from the environment (exposome). Allergies can be regarded as an indirect health outcome parameter in consequence of Climate Change. There is no generally accepted concept for allergy prevention; recommendations go from avoidance towards adaptation and induction of tolerance in early life.

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Nutrition, Movement, and Environment

Ulrich Hildebrandt

Abstract The demand for land for industrialized agriculture associated with the increasing world population leads to the dramatic destruction of our environment. Besides, food production is already responsible for about 30% of global greenhouse gas emissions. To reduce environmental pollution to a necessary level, a sustainable change in diet and food production is required alongside technical solutions to reduce emissions. Currently, animal food production consuming food and feed resources is 5–10 times the amount of a comparable plant-based human diet. Therefore, it is necessary to motivate people to adopt a more sustainable, predominantly plant-based, and even healthier diet. There is a great need for the state to fulfill its ecological and social responsibility by providing financial support or tax breaks for sustainable food options, for example, in school and daycare meals, in canteens, and in hospitals. Comparably effective, incentives for increased physical activity and associated more sustainable forms of mobility can simultaneously improve health and reduce environmental impact. In this context, it is further necessary to make the obstacles transparent that lobbying associations and industry use to try to block sustainable changes and the required legislative amendments due to business interests. In addition to easily accessible knowledge transfer, attractive and practicable instructions for implementation are conducive to optimal motivation. Social and communicative assistance and guidance support a successful, sustainable transition from the initial behavioral change to routinization. In addition to clearly addressing the urgency, the focus should be on positive messages.

Keywords Health · Plant-based nutrition · Physical activity · Behavioral change · Motivation · Environmental burden

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1 Introduction

According to the 2018 international study *Global Burden of Disease* (Lancet), German citizens have the lowest life expectancy compared to all West European countries. Only East European countries have a lower life expectancy. On average, males in Switzerland live four years longer than in Germany. Although 11.2% of the German GDP is spent on health care, which is the highest amount within the EU. What are the causes? An important reason is the simple fact that prevention and health promotion are not taken seriously in Germany.

Germany is the only country in the EU that has not yet executed a prohibition of outdoor advertisement for tobacco products. The previous leader of the parliamentary fraction of a large people's party as well as their economic wing have repeatedly blocked a government bill from 2016 due to "welfare for endangered workplaces."

Similar but less transparent conditions persist in food and agricultural industry. Many other countries have already introduced taxes on or prohibition of excess sugar in baby food and soft drinks. Utilizing a strategy that German tobacco industry applied successfully, the German food industry has forestalled respective legislation. Their measures are counter studies, creating anxieties (i.e., of losing individual freedom), or defaming critics [2].

In no other sector of nutrition health insurances, pediatrics, and other health institutions provide clearer and more explicit scientific data with consequential demands. In many humans, sugar has a similar, even higher addictive potential than smoking. Along with fast food, sugar-sweetened soft drinks, including fruit juices in large quantities, are a major cause that pathological overweight (obesity) and diabetes, especially in children, are increasing significantly. Non-communicable chronic diseases such as coronary heart disease, strokes, dementia, and cancer are becoming increasingly relevant in view of longer life expectancy, despite the progress made by our acute care community.

The knowledge of the importance of healthy diet and exercise has been largely secured for several decades and known to most people. However, there has been little change in the behavior of the individual as well as in the general conditions. What needs to be done? Resigning from the economic forces that drive commercialization and profit maximization? It would be better to utilize the energy and impulse provided by Fridays for Future (even if perceived critically), in order to become active for a better climate and a health-supporting environment. Challenges of preventing Climate Change are similar to the prevention of chronic non-communicable diseases, and both must fight against powerful economic interests.

In any case, changing or transforming any existing conditions means to learn. Successful and sustainable learning, however, requires a simultaneous involvement of different areas in humans (in particular those affective-emotional). In parts, these are known through Pestalozzi's approaches, namely, *learning with head, heart, and hand*. Building on cognitive-intellectual aspects, a long-term anchoring of actions or habits is only possible by means of emotional activation. The mediation of well understandable and verified facts is an important prerequisite for success.

Due to the complexity of the human metabolism, contradictory study results, and of course influences from various interests of the food industry, very contradictory dietary recommendations have been given to date. Low transparency of dependencies and financial links between many food companies and industry complicates an improvement.

2 The EAT-Lancet Commission

Supported by more comprehensive findings in recent years, a group of international scientists from different areas (medical, agriculture, policy, and environmental sustainability) within the *EAT-Lancet* Commission formulated global scientific goals for healthy food and food production with the best available evidence [12]. Only published in early February 2019, these recommendations aim at implementing the United Nations Sustainable Development Goals (SDGs) and the Paris Climate Agreement. According to a big data analysis published in November 2019, the findings of the EAT-Lancet commission were already under attack by the meat lobby just by the time of its publication [5]. This poses towards another health threat resulting from the challenges for science communication posed by "a rapidly changing media landscape and polarization."

The recommended healthy reference nutrition is preferably of vegetables, fruits, whole grain products, legumes, nuts, and unsaturated fats, including a small to moderate amount of fish and poultry. By contrast, no or only a small amount of red meat (less than 280 g per week), of added sugar, refined cereals, and less very starchy vegetables such as potatoes and maize should be consumed. In any case, processed meat is disadvantageous. These recommendations, which are summarized here on the essential statements, have been known for years and are very simple, but are in contrast to the interests of the food industry, which uses all possible means to promote highly processed food at the expense of the environment.

3 What is the Relationship Between Nutrition and the Environment?

There is clear evidence that food production is one of the major contributors to global environmental change, resulting in Climate Change, loss of biodiversity, freshwater consumption and interference with the global nitrogen and phosphorus cycles. Agriculture occupies about 40% of global land. Food production is responsible for up to 30% of global greenhouse gas emissions and for 70% of fresh water consumption.

According to *the EAT-Lancet* Commission, the future planning for food production must be designed in such a way that a world population of around 10 billion people, estimated for 2050, can be adequately provided for. However, already a slight increase in the consumption of red meat or dairy products as a result of increasing prosperity requirements in poorer countries can make it impossible to achieve sufficient food supply for all people. A decisive challenge for a both healthy and sustainable nutrition in the future will therefore be to reduce the consumption of animal products and sugar.

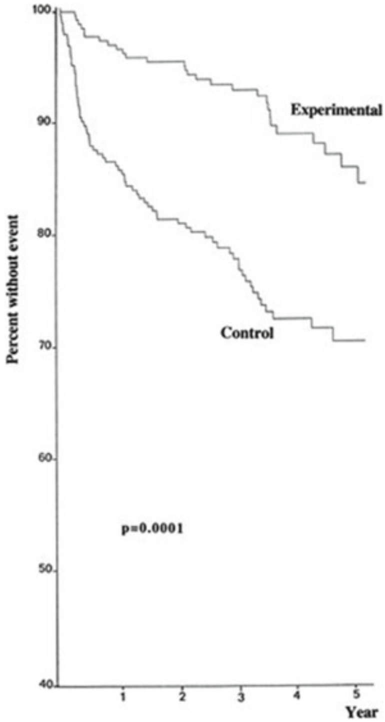

Fig. 1 Cumulative survival without nonfatal infarction and without major secondary end-points (CO_2) (*Source* de Lorgeril et al. [4])

4 Here is an Overview of Some Studies that are Important for a Sustainable Diet

The Lyon Heart Study, published in 1999 in *Circulation*, the most prestigious cardiology journal, ensured that most nutritional recommendations around the world have been rewritten towards a diet similar to a traditional "Crete diet." Three hundred heart attack patients on a "Crete diet" had a 57% lower mortality compared to 300 heart attack patients on a classic cholesterol-restricted cardiologic "heart diet" [4].

A follow-up of more than 120,000 health professionals at Harvard University has shown that the overall mortality rate is about 10% lower with a consumption of 4–5 portions of fruit and vegetables per day [6].

A follow-up to the Nurses Health Study with 84,000 nurses aged 30–55 years showed a decrease in heart attacks of 19% when replacing the required protein supply with meat by protein supply with poultry, of 24% when replacing with fish, of 30% with nuts and of 34% with beans [1].

In 2014, several studies have shown that protein-rich diet is accelerating the aging process. Gerontologist Valter Longo from the Institute of Longevity in Los Angeles was able to show that mortality was 74% higher in people aged 50–65 years who consumed abundant amounts of proteins, especially animal proteins, and that their risk of cancer was four times. High protein advantageously promotes growth during the growth phase in the youth, but at the age of 50–65 years, it seems to promote the growth of cancer cells. At a higher age, this effect seems to disappear higher [8] (Fig. 1).

5 Consequences of Industrial Livestock Production and Rearing

In 2017, agricultural industry used 733,000 t of antibiotics.

As a result, antibiotic-resistant germs are increasingly developing, and many reserve antibiotics available to humans are no longer effective. For example, the WHO classifies Colistin as the last emergency reserve. In Germany, nonetheless, its use for animal fattening increased secretly, while China banned it already in 2015. Because of multiple antibiotic resistance, even young people die in hospitals, and we are re-approaching conditions of the pre-penicillin era.

Residents in areas with a lot of agricultural industry are therefore trying to avoid treatment in local clinics because of the increased antibiotic resistance there.

Increase in extreme nitrogen pollution in agricultural industrial areas: even in the "ideal world of the Chiemgau" (Traunstein and Rosenheim districts), agricultural land with >100 kg nitrogen/hectare adds to the regions with the highest nitrogen surplus in Germany.

The government deliberately accepts fines to the EU resulting from deliberate non-compliance with common EU agreements. Only the application to the European Court of Justice for a “determination of coercive detention against officials of convicted federal states” seems to have prompted Bavaria to consider changes.

Organic cattle also produce only 10–15% less climate-damaging emissions; mainly in the form of methane (greenhouse effect of methane is 25 times stronger than CO_2).

Every day, rainforest the size of 50,000 football fields is cleared, supported by the increasing demand for animal feed for the agricultural industry and for the cultivation of oil palms for the production of palm oil and palm kernel oil (in addition to use as biofuel in the EU mainly for the production of fast food and ready meals; the high proportion of saturated fatty acids in palm and palm kernel oil of 50–80% leads to an increase in LDL cholesterol, among other things).

Against this background, an early quote of Albert Einstein becomes more and more relevant: “*Nothing will increase the chance to survive on Earth as much as the step towards vegetarian diet.*”

Who is not yet so far in its realization, and whose joy of life still depends on the “meat desire,” helps himself and the environment in a first step to orient himself more towards our traditional nourishing way, that limited meat consumption in the form of a “Sunday roast” that is appreciated and celebrated with “good meat” as something special (quantity corresponds approximately to the recommendations of *the EAT-Lancet* Commission 2019: <280 g meat/week, with no processed meat).

6 Can Prompts or Recommendations Motivate People to Eat Less Meat?

“Contribute with less meat consumptionto the fact that in the Amazon region less primeval forests have to be cleared and our local drinking watersupply is not endangered by a higher slurry load!” or “f you are between 50 and 65 years old, enjoying plentiful animal protein, you increase your mortality riskby around 75% and your cancer riskeven four times as well as a high probability for the riskof dementia at age!”

The first recommendation is very unlikely to achieve much, while the second recommendation bases on a personal relationship to one’s own self and has therefore a higher chance of influencing one’s personal diet. In some age groups, however, it can be counterproductive to point out health benefits, since many people do not consider food advertized as particularly healthy to be tasty and attractive. It is therefore better to whet your appetite with messages of pleasure, for example, in combination with deliciously prepared or baked vegetables, or with the Mediterranean cuisine, which is ideal from a nutritional point of view, and which many be associated with positive memories of the Mediterranean (Fig. 2).

Fig. 2 Buffet with Mediterranean crete diet

7 Movement/Physical Activity

The actual data of the National Health Interview Surveys (1997–2008) with 88,140 participants successfully showed, individuals, who reported 150–299 min leisure time physical activity (e.g., brisk walking, dancing, and gardening) per week, had 31% lower risk of all-cause mortality. 1 min of vigorous-intensity (e.g., running, faster cycling, and competitive sports) is calculated as 2 min of moderate intensity physical activity [13]. This study only stands representative of countless others, who have undoubtedly proven the ultimate benefit of regular physical activity as the best preventive measure. In many cases, endurance activity is one of the most sustainable therapies for non-communicable diseases such as coronary heart disease, stroke, diabetes, and cancer.

For those who want to use this insight for themselves: the recommendation with the greatest return on investment (ROI): at least 15–30 min more intensive endurance activity daily with a moderate and more intensive pulse rise at the end.

Despite all recommendations, the "sedentariness" has increased permanently in recent years due to increased use of modern media; currently it is 7.5 h/day. The risk is similar to smoking. In order to better anchor the explosive nature of this fact in our memory, a somewhat more drastic slogan sometimes helps: "Sitzfleisch ist Gammelfleisch" (sitting meat is rotten meat).

8 What is Most Important for Life and Health?

Movement–Movement–Movement, according to Leonardo da Vinci. The chance of actually performing physical activity on a daily basis is more likely when coupled with other everyday necessities, such as getting to work or climbing stairs instead of an elevator. In recent years, several studies displayed the health advantage when using public transport compared to journeys with an individual car.

A growing number of studies show that commuters using a bicycle live longer and have fewer cardiovascular diseases than commuters using their own motor vehicles have. Two long-term studies from Copenhagen and Shanghai proved that the annual mortality of bicycle drivers was 30% lower compared to those commuters who were not physically active on their own [3, 10].

A meta-analysis of seven studies published in early 2019 shows that the use of public transport leads to a lower BMI compared to driving one's own car [9].

The Copenhagen Heart Study (with 5000 inhabitants, 18 years) showed a positive increase of 5.1 years of life expectancy compared to couch potatoes for a daily more intensive use of the bicycle of 20–30 min. The following cost–benefit calculation as a motivational aid: with a daily investment of 20–30 min (= 1–2% of the time of day), men can improve their life expectancy by 5.1 years; with an average life expectancy of 78 years, this means a gain of 6.5%. Such a return on investment (ROI) can hardly be achieved with any medical measure [10].

9 What Practical Political Demands, Among Other Things, Should Result from These Studies?

School and kindergarten meals should play a pioneering role in healthy nutrition. It is easy to understand that none of the recommendations for a healthy diet can be implemented that way.

Consequently, there is a need for policy action in the field of education and training, higher taxation of sugar, meat, and dairy products, and among other things, new attractive, vegetable-based food plans for school and canteen meals, and thus support for regional food production.

The benefits for the health of the individual and for climate development at the same time, make it all the more urgent to expand local and long-distance public transport and to make it more attractive, thereby making bans on private transport superfluous.

Varied beautiful landscapes, especially in connection with water in various forms, represent an important health resource in the sense of health-promoting landscapes. Exercise in such an environment can be an important preventive and balancing measure to protect against overstrain and burnout out and even antidepressive therapy. Therefore, it must be an important task for politics to allow sensitive access to these landscapes, but at the same time to protect them from destruction because of indifference or economic interests in the area of tourism and agriculture.

As a call for action to involve journalists as partners as often as possible, the following example of a rather conservative regional daily newspaper should serve as a motivational precedent. The lecture by a committed regional entrepreneur with frightening pictures of Climate Change in the Alps has concerned the head of the publishing house of a group of local newspapers and sensitized him for the urgent need for action. As a result, very well illustrated information on the subject of the sustainability and Climate Change was published over the period of one month in the newspapers of this particular region in upper Bavaria. The series is entitled, “If all people were living as we do in Germany, we need three Earths.”

10 Recommendations for Action

Understand meat as a luxury and not basic food, and if consumed, enjoying it consciously in high quality in the future. No processed meat, like sausage or the like.

Mediterranean cuisine with products that are as natural as possible, non-processed: a lot of vegetables, legumes, fruit, nuts, whole grain products, olive oil. Retaining with meat, dairy products, and sugar.

Powering up the circulation system for least 15 min/day with endurance activity by involving as many muscle groups as possible, increasing the pulse frequency accordingly, also going towards the limits (Regardless whether dancing, mountain, climbing, cycling, jogging, cross-country skiing, swimming, or the like …).

Whenever you get into a car, consider that there might be a viable alternative.

Discover the staircase as the best training tool and ultimate alternative to the elevator (saves little power, but could motivate companies to develop power savings for the standby function).

As physicians, we should feel obliged to use the trust placed in us to inform and motivate our patients in an optimal and well-founded way to become equally active for their own health and thus make a significant contribution to environmental protection and climate preservation through their individual lifestyle. Among all professional groups, physicians still have the greatest trust among the population and the best prerequisites for shaping this transformative step towards more committed climate and environmental protection.

An important step in this direction is taken by the newly founded German Alliance for Climate Protection and Health (KLUG) in Berlin, an association of actors from various health sectors.

11 Practical Implementation

Before a lifestyle change or a change or transformation, one should recall three important factors for sustainable success.

Transmission of easily understandable and convincing knowledge, the art to inspire oneself or others for the respective goal, practical guidance and practice over a longer period.

In cardiology, in particular, physical endurance activity and a conscious diet have a more lasting effect on life expectancy than stent implantation and bypass surgery. As part of the WHO project *Health Promoting Hospitals,* we developed in 1995, a one–two weeks Heart Life Style Training for motivated heart patients, in order to make possible more medical interventions superfluous, based on the Ottawa Charter. Since then, this training is carried out several times a year on Crete and on Lake Chiemsee in connection with the Kardioforum Bayern. Flanking heart seminar weeks with an intensive program consisting of varied lectures, Mediterranean cooking courses, relaxation programs, and intensive physical training, partly also in the form of a cardio trekking with a 1 week mountain hike from Lake Chiemsee to Lake Königssee and from Lake Chiemsee across the Alps to Italy. To integrate the mediated lifestyle changes successfully into everyday life, the participation of the spouse is very desirable.

The six pillars of a healthy body and environment:

1. **sound knowledge about body and soul**
2. **physical activity daily for 20–30 min**
3. **eating preferentially vegetable and fruits, but less meat, carbohydrates**
4. **cultivate humor and a meaningful lifestyle**
5. **appreciate social ties, trust, and social engagement**
6. **experience nature consciously**.

Due to the holistic approach of this program [7], the lifestyle of most of the more than 1000 participants had been influenced sustainably. The goal of both the "Herzwochen" on Crete and in the abbey of Frauenchiemsee and the "Kardio-Trekking" is to inspire and enable participants to become active for their own health and to take responsibility for the "health" of their own social and natural environment.

As an introduction to this program, the Munich Physician Patient Forum takes place annually since 1991, together with leading cardiologists from the Munich Heart Centers at the Hotel Bayerischer Hof and the Old Town Hall in Munich. In this context, it is also important to sensitize speakers from the more conservative field of interventional medicine to the connection between health and the environment.

The two major American heart companies, American College at Cardiology (ACC) and the American Heart Association (AHA) have initiated the publication of their new guidelines on the primary prevention of cardiovascular diseases. Today, we are talking about the fact that we can prevent 80% of all cardiovascular diseases by adapting the lifestyle (John J. Warner, Past President of the American Heart Association). The 6-Säulen-Programm of the Bavarian and Crete Heartweeks in cooperation with the Kardioforum Bayern, which has been successfully implemented for several years, complies with these new guidelines.

12 The Power of the Small Steps

> The problem braiding arose by the assignment of each individual can/must within the scope of its possibilities to solve the whole [11].

To a similar extent as human health and life expectancy can be influenced by prevention, it is also possible to influence the "health" of our planet, in large as in small, by using the power of many small steps in addition to great efforts and actions.

The effect of these small steps is so significant because the health of our planet on a large scale and the health of our surrounding landscape on a small scale is closely linked to our health.

A natural, and therefore, usually healthy landscape is a very important resource for our own health. We use the landscape as a space and motivation booster for movement, encounter, and regeneration.

Particularly in combination with water in the form of streams, rivers, lakes, and the sea, landscape stabilizes our mental balance to a special degree, and in combination with exercise, has a comparable effect to an antidepressant. Landscape thus becomes a health-promoting landscape. The awareness for this meaning is not yet very pronounced and usually only develops after it has been impaired and destroyed.

In order to strengthen the awareness for health-promoting landscapes and to create not insurmountable resistance against the necessary protective measures, a path of small steps on different levels is usually the most successful. Good ideas for the practical implementation of these small steps are most likely to emerge during one's own physical activity in such a health-promoting landscape.

However, prevention will always cause conflicts of interests. The effort to achieve this will therefore remain one of the greatest challenges, both globally and personally.

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The Future of Cancer Therapy with X-rays: Patient Numbers, Innovations, Clinical Trials, and the Problem of Generating Evidence

Michael Molls, Hendrick Dapper, and Hanno Specht

Abstract When Roentgen discovered the X-rays 125 years ago, his finding was soon recognized as a breakthrough in research and awarded with the Nobel Prize. Today X-rays are widely used in natural and applied sciences and even art. In medicine, X-rays have made an impressive impact far beyond their original domain of diagnostic imaging. In cancer treatment, X-rays are indispensable for reaching the goal of uncomplicated and lasting tumor control. Using the possibilities of modern technology and the innovative mind of physicians and physicists, definitive cancer cure cannot only be achieved by combination of surgery and radiation, but also by radiotherapy alone. One prominent example is the application of single high radiation doses with optimal geometrical precision through image-guided stereotactic radiotherapy. The article aims to highlight past, current, and future sustainable developments in oncology in general, but in radiation oncology, especially. We discuss the very complex challenge of generating evidence by clinical research. In this context, the tumor registries play a very important role. The data of tumor registries and the results of clinical studies demonstrate the benefit for cancer patients who experienced individualized radiotherapy. For cancer cure, it is most important to treat in an early, localized stage of the disease.

Keywords Sustainability in clinical cancer research · Early tumor detection · Individualized curative radiation treatment · Outcome research · Ethical responsibility

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1 Introduction

Wilhelm Conrad Röntgen discovered the "RÖNTGENSTRAHLEN" at the University of Würzburg on November 8, 1895, for which he was awarded the first Nobel Prize for Physics in 1901. In 2020, we celebrate the 125th anniversary of this "big bang" of research. Many scientific fields owe their enormous progress to the application of "X-rays." This applies not only to medicine, but also to biology with X-ray diffraction when the rays pass through crystals, e.g., to clarify the structure of DNA and proteins, extraterrestrial physics and the exploration of the cosmos, e.g., within the framework of the eROSITA project, engineering sciences with non-destructive material testing, art history with the X-ray analysis of paintings, etc. X-rays "illuminate" inanimate as well as animate matter; they open up molecular worlds of the small and the huge expanses of space.

X-rays are used in medicine for diagnostic and therapeutic purposes with great benefit. However, it became clear early on that they can also damage biological systems. Permanent inflammatory processes have been observed in human tissues and organs as a result of radiation treatment, for example. It was also recognized that X-rays can trigger the development of malignant tumors and leukemia. It is said that Röntgen wrote the sentence: "Where there is a lot of X-rays light, there must also be X-ray shadows." This article deals with X-ray therapy of cancer diseases, also in combination with medication. It outlines hopes for the future as well as critical developments in clinical research that need addressing. Medicine plays a major role in the fact that people are getting older and older, and the number of cancer patients is increasing significantly: An unfavorable side effect of medicine! On the other hand, X-ray therapy is relatively inexpensive with a high healing potential. In this context, the question of tumor induction through radiation application and cancer therapy of elderly people is almost negligible.

In general, doctors are aware of the "dark sides" of diagnostically or therapeutically prescribed measures. Also, in case of using X-rays, the expected benefit of the "intervention" must be clearly greater than the conceivable damage. The weighing up of benefits and risks has always been part of medical thinking and decision-making. Thus, the Hippocratic Oath obliges doctors to observe ethical principles in the care of the sick. The perception of responsibility also extends to medical research, i.e., the realization of new and better possibilities for early disease detection, diagnosis, and therapy. The future of clinical and scientific radiotherapy and radiooncology must be shaped in this sense of a comprehensive responsibility towards both the individual patient and the society.

Specialists in radiotherapy mainly treat cancer patients. The vast majority of therapies are performed using X-rays (photons) at the linear accelerator. The accelerator generates X-rays by decelerating electrons. Today, about 60% of all cancer patients in Germany receive curative or palliative radiation treatment. Viewed globally, the absolute number of radiation therapy patients is constantly increasing.

Modern radiotherapy means, "personalized therapy planning," including CT, MRT, and PET imaging (CT: computed tomography; MR: magnetic resonance imaging; PET: positron emission tomography). In addition to the "data" of the imaging, further parameters and findings of the individual patient are taken into account in the planning. These include, above all, the disease status (TNM system) and special biological characteristics of the tumor, such as growth rate and metastasis tendency, more specific genetic and molecular biological patterns (e.g., hormone receptors on the surface of the cancer cells), etc. Within the framework of this personalized planning process of radiation therapy, medical physicists together with physicians calculate and determine the distribution of the radiation dose in the body of the individual patient. The calculation of the dose distribution on the computer, in which sparing of healthy structures is given the highest priority, is followed by the implementation of the planning, i.e., the real irradiation at the accelerator. Per entire treatment cycle, only one, few, or up to approx. 35 irradiations are performed, usually one irradiation daily. The radiation doses vary depending on the radiation technique and the disease situation: one-time "very high" doses (e.g., stereotactic radiosurgery for brain metastases), few high doses (e.g., stereotactic fractionated radiation therapy for lung carcinoma) or many, relatively low dose portions (e.g., intensity modulated radiation therapy or conventional 3D radiation therapy for prostate carcinoma or postoperatively for breast cancer).

The precision of the beam application has recently been further improved, since the newer accelerator facilities are equipped with a computer tomograph (CT) in the form of an "integrated" technology, and more recently also with a magnetic resonance tomograph (MRT). This way, the tumor region and the surrounding healthy tissue can be visualized at any time in the patient's irradiation position, and the accuracy of the beam guidance can be regularly checked. This is referred to as "Image Guided Radiotherapy" (IGRT). Details on IGRT are described below.

2 Future Developments in Patient Numbers, Early Tumor Detection, and Cure in Radiooncology

The increase in the number of radiotherapy patients in highly developed industrial countries such as Germany, but also worldwide, is due to the growing number of elderly people. With increasing age, the probability of developing cancer increases significantly. Older women and men are more frequently affected by cancer than younger people. With regard to therapy, it can be seen that the risks of surgical intervention increase with increasing age and corresponding co-morbidities. Thus, older tumor patients sometimes cannot be operated sensibly or they—like younger patients—decide against an operation. This is reasonable, since non-invasive X-ray therapy offers good chances of cure, especially in non-metastatic, early stages of cancer.

A future increase in the number of "radiotherapy patients" can be expected for the following reasons: Screening (e.g., highly sensitive blood tests) and **early detection of tumors** with imaging will receive much more attention and research funding in the coming years. From a strategic point of view, screening and early detection are the real keys to **defusing the cancer problem**, along with prevention. About 45% of those affected still die of their malignant disease! Every experienced surgeon and radiotherapist who has treated a significant number of cancer patients knows: Patients in early stages (T1 tumors, no lymph node or distant metastases) are very likely to be cured by local therapy, but many patients with advanced cancer will eventually die from their tumor despite all therapeutic efforts (surgery, radiation treatment, cancer drugs). In a nutshell, early detection of the carcinoma and subsequent therapy means cure.

In short, new technologies for the application of X-rays are promising for the screening and visualization of early-stage lung cancer. The corresponding research on dark-field imaging using a grating interferometer by physicist Franz Pfeiffer at the TU Munich (Leibniz Prize 2011; Röntgen Medal 2018) in collaboration with clinically active radiologists is attracting a great deal of international attention [15].

X-ray mammography screening has reduced the number of advanced, prognostically unfavorable breast carcinomas by approx. 20% [10]. The number of early detected, largely curable breast tumors (T1 stage) is increasing. Currently, lung screening using computed tomography (CT) is under investigation in North America, Europe, and Asia. The US Preventive Services Task Force recommends lung cancer screening for individuals aged 55–80 years with 30 pack-years (average consumption of 1 pack of cigarettes per day over a period of 30 years). This applies to both active smokers and former smokers who quit smoking within the past 15 years [25].

The importance of early detection from a radio-oncological point of view is as follows: Non-metastatic carcinomas of early stages can be cured in high percentages with only modern X-ray treatment. In the case of early (!) discovered primary tumors with small diameters, the volumes to be irradiated are relatively small. In combination with the application of high-precision irradiation techniques, this means that therapy is particularly gentle and low-risk. The non-invasive use of X-rays at the accelerator is therefore very attractive for cancer patients. This is especially true when—as in the context of "Stereotactic Radiation Therapy of Lung Cancer"—only a few fractions or a few higher single doses can be given on an outpatient basis. This means that the number of radiotherapy patients will continue to rise even based on a gradually more widely established early diagnosis.

From a realistic point of view, there is no evidence that chemotherapy or even the new immunotherapies will replace palliative, but above all curative radiotherapy. In terms of local tumor destruction, radiation is fundamentally superior to the various cancer drugs. This will be explained here briefly.

First, we take a look at **palliative cancer treatment**. Current publications on cancer patients with few metastases (*oligometastasis*) show a clear benefit of local radiation therapy. In oligometastasized patients with lung carcinoma, the probability of survival after initial chemotherapy followed by a local (!) treatment of the metastases (radiotherapy 72%, surgery 4%, and combination 24%) was about 50% after 5 years. In contrast, the survival rate in the control arm of the study with chemotherapy alone was only 0% [7]. In this high-ranking published study, the median overall survival in the group with additional local treatment (radiotherapy) was 41.2 months, in the group with drug-only therapy 17.0 months. With this clear difference, the "Data and Safety Monitoring Board" recommended to terminate the study prematurely after randomization of only 49 patients in order not to deprive patients of the option of consolidating local therapy (radiation therapy) [3]. This publication by Gomez et al. and other publications on palliative radiation treatment of metastases can be interpreted as an indication of the high efficiency of X-rays in the **permanent local destruction** of cancer cells or metastatic tumor foci.

In **curative cancer therapy**—as mentioned above—the exclusive treatment with X-rays in very early stages of tumors in a high percentage leads to healing (e.g., carcinomas of the skin, the anus, the ENT area, the prostate, etc.). Even with the problematic and rather aggressive lung carcinomas, favorable results can be achieved with radiation therapy alone. For inoperable, older patients with early, small lung carcinomas, our group at the Klinikum rechts der Isar of the TU Munich was one of the first in the world to show that 3 years after stereotactic radiation treatment with 3–5 radiation fractions, about 75% of the patients survived tumor-free. The local tumor control after 5 years for T1 and T2 carcinomas was 100% and almost 80% [26].

For larger, localized tumors without distant metastases, radiotherapy is combined with chemotherapy (e.g., carcinomas of the anus, the ENT area, the lungs, the cervix, the bladder). With additional chemotherapy, i.e., radiochemotherapy, the healing rates improve by about 10% compared to radiotherapy alone, e.g., for larger ENT carcinomas with local lymph node metastases (T3/N+) from about 40% to about 50%. It can be speculated that the combination of radiotherapy with immunotherapies such as checkpoint inhibitors for subgroups of patients with certain cancers and genetically unstable tumors will bring further improvements in cure rates (for cure after radiotherapy alone or after radiochemotherapy: see relevant monographs and publications in radiooncology).

The efficiency and success of local radiation therapy can be explained by radiation biology. **Radiation generally destroys a very high number (!) of cancer cells**. Compared to chemotherapy, the "cell death" is higher by orders of magnitude or powers of ten. Against this background, it is clear that X-rays can be seen as an alternative to surgery in the curative treatment of solid tumors in adults, also from the point of view of preserving the organ (e.g., in the case of cancer of the anus, larynx, lungs, prostate gland, urinary bladder, etc.). In combination with chemotherapy for locally advanced tumors, the drug's additive "cell kill" effect is advantageous. In the case of large tumors with many cancer cells, radiation therapy—as already mentioned—generally leads to extensive cell destruction. However, this may not be sufficient. In such cases, chemo- or antibody therapy running at the same time as radiation treatment contributes additively and ultimately decisively to the fact that at the end of the treatment all (!) tumor cells are killed. Local tumor healing is thus achieved! Many cancer cells are destroyed by X-rays, a smaller additional part by the cancer medication.

3 Technological and Drug Innovations in Radiotherapy with X-rays

The research and development work of medical physicists, computer scientists, engineers, biologists, and physicians has given radiotherapy an enormous boost in the past decades, especially on the technological side. Completely new, more precise procedures for the application of X-rays have led to a very high level of quality in the protection of healthy tissue structures inside the patient's body. These innovative forms of irradiation in the sense of stereotactic radiation treatment, IMRT, and IGRT are also inherently more efficient in destroying cancer cells and treating malignant diseases. Better protection allows the application of higher radiation doses (e.g., IMRT for prostate carcinoma). The probability of definitive tumor destruction increases.

A number of diseases, e.g., brain metastases, primary lung carcinomas, prostate, and mamma carcinomas, etc., are now treated with a radiotherapeutic precision that was unimaginable in the past. In addition, the individual work steps in the overall course of radiation therapy have become clearer, easier to carry out, better controlled, and in some cases faster, particularly through IT control or the use of appropriate software. Thus, the new technologies and the procedures they make possible, serve not only the protection and effectiveness, but also the "comfort" of the patients. The developments have not reached an end. With a very high level of technology, it can be said that there is potential for further innovations and optimizations.

In the next decade and beyond, radiotherapy will continue to benefit from new developments in the field of imaging. Artificial intelligence (AI) will further advance image recognition and image analysis in detail. Special imaging methods will make it possible: (1) to make even more precise distinctions between tumor edges and adjacent normal tissue, and (2) to record individual biological characteristics of the tumors in relation to total volume and subvolumes in greater qualitative and quantitative detail than before, especially with regard to the question of radiation and drug sensitivity.

As described in the introduction, "imaging" serves as the basis for personalized radiotherapy planning on the computer. Future procedures for the anatomical and biological visualization of tumors will bring further increases in precision of the upfront calculation of individually "designed" dose distribution plans. This increased precision in treatment planning through a more precise 3-dimensional definition of the target volume to be irradiated, and a more differentiated prediction of the sensitivity of the tumor to exclusive radiation treatment or combined radio-drug therapy will further raise the level of therapy quality by a significant amount.

Image Guided Radio TherapyIGRT) is an important technological innovation in radiotherapy. In the performance of daily patient irradiations, imaging with computed tomography integrated into the accelerator (more recently also magnetic resonance imaging) increases the accuracy and safety of beam guidance. Future improved software will further refine the "interaction" between imaging on the one hand and beam application control on the other hand, which is controlled by physicians and physicists. All in all, advanced imaging in therapy planning (see above), together with further developed and innovative hardware and software for image-controlled beam application at the accelerator, will serve to provide optimal treatment for the individual patient.

The **technologically "highly intelligent" accelerator of the future** will be very close to the ideal situation of having the greatest control at all times under irradiation to correctly detect the very precisely defined tumor volume. Already today, the movement of a tumor under irradiation (e.g., lung tumor during inhalation and exhalation) can be taken into account in so-called 4-D radiation therapy by using special techniques. Radiation is always computer-controlled only if the tumor is in a certain, defined position of the spatial coordinate system while breathing. This serves to protect healthy lung tissue, because the total target volume to be irradiated (tumor plus surrounding safety margin of lung tissue) can be kept comparatively small when using the "breath gating" technique. With less modern irradiation technique, it must be taken into account that the tumor makes major changes in position under irradiation due to the patient's breathing: during inhalation towards the upper abdomen, during exhalation towards the shoulder. The tumor, which must receive the full radiation dose, must not be allowed to move out of the radiation field. In order to avoid this, the tumor is irradiated with a relatively large surrounding safety margin of healthy lung tissue (relatively large total volume) over a comparatively large radiation field.

A completely new technological option is the so-called **"flash" radiation therapy** with particularly high dose rates (several hundred times higher than in today's radiation therapy). Industrial manufacturers are currently working on the realization of this accelerator option [16]. Based on theoretical and experimental findings, it is discussed that the application of a radiation dose in milliseconds (!) can further increase the effectiveness of cancer therapy with X-rays.

"Microbeam" radiation therapy with X-rays at synchrotrons is also currently still an experimental therapy. Here, the radiation is applied via spatially separated microbeams with diameters of approx. 25–75 μm. Peak doses of up to 100 Gy are achieved per irradiation. It is discussed in the literature that this form of radiotherapy could be advantageous, e.g., for brain tumors. Preclinical research to date shows that the healthy brain tolerates these high doses in separated microbeams well. At the same time, tumors in the brain of experimental animals showed high rates of tumor control [9]. In our own experimental studies, a compact light source was used to generate X-ray microbeams using laser technology [2].

It is also briefly mentioned: For poorer regions of the world (e.g., Africa) with still poorly developed infrastructures, more and more inexpensive and "robust" accelerators will be needed in the future as the number of cancer patients increases. The industry seems to be prepared to take this aspect into account.

Recent developments in **brachytherapy** aim to replace "conventional" emitters (e.g., 192Ir, 60Co) by miniaturized X-ray devices as far as possible. These are inserted into the patient's body or brought into contact with the patient's skin. This procedure is called electronic brachytherapy (eBx). The miniaturized X-ray tubes are operated with a voltage of 50–100 kVp. Systems such as the Xoft (iCAD), Intrabeam (Zeiss), Papillon (Ariane), Esteya (Elekta), Photoelectric Therapy (Xbeam), and SRT100 (Sensus Healthcare) are used for the treatment of skin, endometrial, cervical, and breast tumors. Comparable to the radionuclides used in brachytherapy, they have the favorable property of a very steep dose drop at the transition from the tumor margin to adjacent healthy structures. Compared to the radionuclides, they offer the advantage of less shielding effort (spatial radiation protection!) and the "on–off" operating mode.

Finally, in the technological context, it should be pointed out that there are possibilities that will play an important role in radiooncology in the future: Home monitoring by means of "**healthapps**" which control specific radiotherapy-related parameters. Such apps allow, for example, the rapid detection of side effects of radiation therapy or radiochemotherapy. The early introduction of appropriate treatment measures is supported [12]. In addition, apps on smartphones or tablets will also be useful in the future for accompanying the performance of radio-oncological research on patients, e.g. in the context of studies [23].

In summary, the previous paragraphs show the rapid technological advances that have taken place in the discipline of radiooncology in the recent past, but which can also be expected in the future. Despite all the technological innovation and software-controlled "automation" of working and irradiation processes, however, it is very important to emphasize at this point: **As in the past, physicians and physicists will continue to be the "drivers" of the technologies in the future by applying them in a targeted and well thought-out manner for the benefit of patients and by monitoring their functionalities**.

Above, the combination treatment of radiation with cancer drugs was mentioned. The "**checkpoint inhibitors**" are a new group of tumor-effective substances for whose development James P Allison and Tasuku Honjo received the Nobel Prize in 2018. They have an immunological effect and have been in clinical use for some time, also in combination with radiotherapy [5]. Of particular scientific interest in this combination is the "**abscopal effect**" (ab scopus = far from the target) of radiation. The latter was already described decades ago as a tumor regression outside the irradiated area. More recently, there have been indications, especially from experimental investigations in animals but also from clinical studies, for the irradiation of a single metastasis leading to extensive volume reductions even in the non-irradiated foci when using immunologically active substances [4, 17]. The experimental observations show that radiation can trigger different immune mechanisms. Against this background, the enhancement of the effect of checkpoint inhibitors on metastases by low-volume irradiation of a single spot is currently being discussed as a future option for palliative cancer treatment and is increasingly the subject of clinical research. The combined treatment of metastatic cancer patients with immunotherapeutic drugs plus X-rays could lead to significant life prolongation.

4 Personalized Radiotherapy of the Future

About 35 years ago, radiobiologists of the Institute for Medical Radiobiology at the University Hospital Essen, in cooperation with pathologists, radiotherapists, and surgeons, intensively researched the individualization (!) of cancer treatment (e.g., [21]). Today, the term "**individualized therapy**" is replaced by the term "**personalized treatment**."

IT will play a very far-reaching role in the personalized radiooncology of the future. Using "self-learning systems," the diverse information and data on individual, currently diagnosed patients will be compared with the data and courses of corresponding cancer patients who have been treated earlier and who have undergone long-term follow-up observation. With regard to the tumor, the data pool of both patient groups will include genomic, proteomic, metabolomic, histopathological, cell kinetic, etc., findings also include "patterns" from morphological and functional or biological imaging in the sense of radiomics. Comparisons between current and previously treated patients require a systematic collection of data, including results from control examinations after radiotherapy. The continuous comparison of new and old data, supported by information technology, gradually leads to a differentiated knowledge gain. This continuous "learning process" will lead to the fact that in the future, the therapy of the individual patient can be adapted more precisely than today to the given tumorbiology and overall situation of the patient.

Modern forms of high-precision X-ray radiation therapy at the accelerator open up special application variants for personalized treatment. On the basis of the "Intensity Modulated Radio Therapy" (IMRT), the so-called "dose painting" can be carried out. The radiation dose distribution is specifically calculated inhomogeneously for the individual patient in order to take into account the biological heterogeneity of the tumor. The IMRT technique allows the application of extra high doses in radiation-resistant subvolumes of the tumor. Relatively early, our group was able to show for patients with ENT disorders that tumor hypoxia (undersupply of oxygen to the tumor) is one factor of resistance, which can be visualized with PET imaging. This PET positive, hypoxic area of the tumor can be specifically "addressed" by the radiotherapist using IMRT, and simultaneously irradiated with a higher dose compared to the rest of the tumor volume [8, 20].

In addition to the further developments outlined above, it is also foreseeable that innovative micro-technologies for supporting and "refining" personalized X-ray therapy alone or in combination with immune therapies will find their way into cancer medicine. The so-called "smart probes," for example, should be considered. These microprobes deposited in the area of the tumor will register tumor biological parameters and report their qualitative and quantitative changes to a recipient during therapy. In this way, a very early assessment of the efficiency of the X-rays in destroying cells can be made. In the future, the radiotherapist may be able to carry out targeted modulations of the rhythm of fractionation, amount of individual and total dose, dose distribution pattern, etc., at short notice, if necessary also an additional application of tumor-effective drugs. A comparable potential can be anticipated for "liquid biopsies." Liquid biopsies here means the examination of body fluids. The future perspective is that, for example, cancer cells circulating in the blood and/or molecular "markers" (e.g., cell-free DNA) can be used to monitor the effectiveness of therapy and to assess the current status of cancer.

5 Clinical Research, Evidence Generation, and Ethical Responsibility

In the future, in view of a variety of new therapeutic options resulting from translational, preclinical research, the topic of "generation of evidence" through clinical studies will have to be discussed much more intensively than before. On the one hand, financial resources are limited and, on the other hand, modern societies are rightly pressing for better cancer treatments to find their way quickly into clinical routine. Accordingly, the conditions under which clinical research is conducted should allow progress to be made as efficiently as possible. Therapy innovations must be ethically responsible and bring significant benefits to cancer patients.

With regard to **ethical responsibility**, the authors are guided by the empirical concepts of **utilitarianism** (from Latin *utilis*, i.e., useful), which was first discussed in Scottish and then in British moral philosophy. Here, the moral goodness of an action is measured by the fact that it serves the goal of the greatest possible happiness for the greatest possible number of people. Not the underlying good intentions of an action are at the center of ethical reflection, but the number of people for whom the benefits of "well-being" can be generated or—in retrospect—have been generated. With reference to clinical-oncological research, utilitarianism thus means the realization of the idea through scientific work to provide as many cancer patients as possible in the future with a high prospect of success and ultimately as much "good" (healing, at least significant improvement) as possible. In this sense, utilitarianism as a superior "guideline" seems to be reasonable and correct to the authors. In Great Britain and many Commonwealth countries, utilitarianism has become the dominant model in medical and bioethical discourse. The following remarks will show the importance of outcome research in cooperation with tumor registries in the context of ethical responsibility. When it comes to generating evidence and progress, **epidemiological research on the basis of registry data is of the greatest value.**

In the field of adult oncology (carcinomas, sarcomas), a huge number of studies have been conducted over the past three to four decades to generate evidence and establish better therapies. Against this background, the question of progress in cancer therapy inevitably arises. Over the past decades, the Tumor Registry at the Munich Tumor Center has collected abundant data that is freely accessible on the internet. The observation of relative survival in past and present periods is a particularly interesting parameter. The relative survival corresponds to the probability of survival of cancer patients compared to a cohort of non-cancerous patients in a defined period of time, adjusted according to age, gender, and ethnicity. Thus, the influence of cancer on survival and, when comparing different time periods, the influence of medical progress on the prognosis can be determined. The following corresponding figures are for the most part rather disappointing.

If we compare the period 1988–1997 (4865 patients) with the period 1998–2011 (12,413 patients), the following figures for relative 10-year survival are found for colon carcinoma related to UICC stages I, II, and III: 90 versus 86%, 74 versus 74%, and 50 versus 56%. For lung cancer, the figures for the period 1988–2017 (17,322 patients) versus 1998–2017 (14,978 patients) in UICC stages I, II, and III are 54 versus 55%, 26 versus 28%, and 3 versus 3%. Also in pancreatic carcinoma and glioblastoma (malignant brain tumor), there are no relevant increases in cure rates. The relative 5-year survival for pancreatic cancer (all stages) is 9, 9, and 12% in the periods 1988–1997 (768 patients), 1998–2006 (2659 patients), and 2007–2017 (5693 patients). Also for glioblastoma, the relative 5-year survival in the period 2007–2017 (1724 patients) is still slightly below 10%, which is a certain but not a resounding improvement compared to the previous period 1998–2006 (5%, 868 patients).

In the case of breast carcinoma, the focus is exclusively on patients who have had larger breast tumors (T3 or T4) with lymph node metastases or distant metastases at the time of primary diagnosis, for the period 1988–2017. In these advanced stages, the relative survival after 10 years is 48.7% (1632 patients with T3 tumors and lymph node metastases), 31.8% (1426 patients with T4 tumors and lymph node metastases), and 12.5% (3978 patients with distant metastases). According to international literature, when all stages of breast cancer are considered, the 10-year cure rates increased by approximately 10%. In the Munich tumor register, the relative survival for the time windows 1988–1997 (10,611 patients), 1998–2006 (18,883 patients), and from 2007 (30,636 patients) is as follows: 72, 77.7, and 79%. The 10% improvement in survival is due in no small part to the fact that the number of patients diagnosed in the earliest T1 N0 stage has recently increased. In the case of non-metastatic tumors with diameters of approx. 1–2 cm (primary tumors of the breast but also of the uterus, prostate, urinary bladder, colon, lung, ENT area, skin, etc.), which are detected very early, healing rates after local therapy (surgery, radiation treatment, or both) have always tended towards 100%, even in the past. Accordingly, no further progress was and is expected for the early stages of the cancer diseases.

The decisive question is whether significant improvements in therapy results can be found for later (!) stages. Considering the facts and figures mentioned above, the answer is sobering. Full-bodied statements from the field of research as well as from pharmaceutical companies, who repeatedly spoke and still speak of "revolutionary therapeutic innovations," are deceptive.

On the positive side, however, it should be emphasized that the newer drug-based immune and antibody therapies lead to longer survival times, for example, in a smaller subgroup of breast cancer patients (Trastuzumab) or in the rather rare malignant melanoma (Ipilimumab and checkpoint inhibitors). However, it remains to be seen how extensive these life-time gains will be in a few years' time, taking into account extensive epidemiological data from cancer registries. These drugs will not lead to definitive cures either.

A smaller part of the clinical studies conducted globally was dedicated to radiotherapy (with or without chemotherapy). For example, recent phase 2 studies show the benefits of "Stereotactic Hypofractionated Radiation Therapy" in lung cancer [1]. The radiooncologist Rolf Sauer at the University Hospital Erlangen initiated the "rectum study" with surgical colleagues, which is a trend-setting study for preoperative radiochemotherapy [18].

The vast majority of studies examined the effectiveness of drugs. There is no doubt that there are highly valid examples of studies on chemotherapy, hormone therapy, and immunotherapy. However, the immense number of oncological drug studies will not be discussed in detail in this article dedicated to X-rays. It is important to note that, under the cloak of a supposedly meaningful study design, irrelevant small therapy effects are often considered a gain. Epidemiological results of the "Outcome Research" of tumor registers contradict this outcome (see above). The registries, with their extensive data pools on large cohorts of surviving and deceased cancer patients, create a picture that truthfully characterizes progress in cancer treatment on the one hand, but also the widespread stagnation on the other. The dark sides of clinical cancer therapy research within the framework of studies become evident.

Against this background and due to the relevance for health policy, it is necessary to discuss in oncological medicine and society how the chances of establishing clearly beneficial therapies could be significantly improved. How can we achieve clearly positive evidence in clinical cancer research at a faster pace than before? Of course, the authors cannot present a comprehensive solution here. However, they dare to attempt to introduce some suggestions into a debate that needs to be conducted. They follow the utilitarian idea of achieving as much good as possible for as many cancer patients as possible in the future.

First, a provocative question is formulated: Why does clinical cancer research still initiate a myriad of prospective (randomizing) **studies** when registry data show that the majority of statistically better therapies (corresponding p-value!) ultimately do not bring any clearly visible advantages in the broad range of therapeutic care for cancer patients? Is the current "study culture" still responsible towards society and the patients participating in studies? What does the "fixation" of clinical researchers on "p-values" in the hope that they will reach the significance level mean? Recent publications, including a *Nature* journal editorial from March 20, 2019, discuss the insufficiently reflected handling of statistics and the significance level [14]. In Wasserstein et al.'s [24] works, this statement: "Statistically significant," or "not statistically significant" is too often easily misinterpreted to mean either "the study worked," or "the study did not work."

Against this background of a somewhat problematic "study culture," it should also be mentioned that many oncological studies approved by ethics committees have to be discontinued due to insufficient patient recruitment. The latter certainly has good reasons in part. These are not discussed in detail here. With regard to personnel, funds, and the provision of institutional infrastructure, however, the discontinuation of a study represents a fundamental waste of resources and in some cases a violation of the interests of the study patients.

Finally, it should be noted that since 2004, all EU clinical trials of medicines have to be recorded, and since 2014, the results of these trials have to be included. In Germany, 1312 studies from different medical fields including oncology have been registered. Four hundred and seventy seven studies have been completed, but for only 32 (6.7%!) results can be found in the European Register. Currently, there are notable failures to report results for the Charite/Berlin, the two Munich university hospitals and the Hannover Medical School [22; Deutscher Hochschulverband 2020). The "withholding" of results means leaving open questions that the sick and society are urgently interested in having answered. It can be assumed that the institutions named will fulfill their obligations with a time delay. All in all, however, the particular ethical "omens" under which clinical research is conducted become clear once again when these facts are considered. Clinical scientists who are involved in studies should be aware at all times and in every respect of the far-reaching responsibility, they bear in their research (see introduction: "Hippocratic Oath"). The authors of this book contribution emphasize this aspect very consciously. They had to experience that they could not achieve the goal in high-ranking, randomized studies in cancer patients. This led to study cancellations, which was very regrettable in view of the patients involved in the studies and the potential gain in knowledge from the implementation and evaluation of the study.

A second idea focuses on the activities and structure of **ethics committees**. If the assertion that many studies are of little use is a step in the right direction, it should be considered, among other things, whether ethics committees should not discuss much more intensively than hitherto to what extent a new study has a really promising "potential for progress." In the view of the authors, the theoretical and experimental foundations of a new approach should be discussed in detail.

In clinical cancer research, we must not pretend that we are always at a trial concept to be tested in a completely new, completely open situation. With regard to drug therapy, for example, the fact that no decisive breakthrough in the treatment of metastasized adult patients (exception: testicular tumors) has been achieved over decades with regard to definitive cure should give cause for fundamental reflection. The authors do not ignore the fact that treatments with antibodies such as Trastuzumab or checkpoint inhibitors lead to significant prolongation of life in smaller subgroups of patients with solid tumors. Nevertheless, even with the new drugs, complete cures cannot be achieved. Like the traditional chemotherapy substances, they do not have the efficacy to bring about a definitive local control by destroying all cancer cells in the individual metastases or tumor foci.

For future studies with new cancer drugs, the fundamentally important question arises again and again whether the drug reaches the tumor tissue in sufficiently high concentrations, whether the drug or the immune cell stimulated by the drug develops sufficient activity on and in the cancer cells to be biologically efficient in terms of extensive cell destruction. For example, the tumor-typical "chaotic" vascular structures with reduced blood perfusion of the carcinoma tissue and the pathophysiologically altered microenvironment (hypoxia, acidosis, etc.) in malignant tumors can counteract the effectiveness of chemo- and immunotherapies [11, 13]. In current clinical research, the treatment of such fundamentally important questions about the "kinetics" of cancer drugs in tumor tissue and in the cancer cells themselves (are the molecular targets reached in sufficient concentration?) is not sufficiently present. From the radiotherapist's point of view, however, such research is also urgently required, since many radio-oncological treatment concepts combine radiation with cancer drugs.

A completely different point is the staffing or structure of ethics committees. Here, the question should be introduced into the debate as to what extent these should be developed into institutions that are much more broadly anchored in society in terms of their responsibility. A concept should be considered which comprehensively includes the "responsible citizen and patient" (e.g., patient associations) as well as the "stakeholders" of the health care system (e.g., the cost bearers). In such a constellation, the responsibility for determining the direction of clinical research on new oncological therapies would no longer lie primarily with the physicians and study sponsors. In view of the limited progress in cancer therapy and the considerable waste of resources, it must be possible to rethink the traditional institutionalization patterns of ethics committees with regard to their composition and competences. The science philosopher Paul Feyerabend has formulated it as follows: "Traditions are always only better or worse in relation to the interests, wishes and goals of people" [6].

The ethics commission of the future, envisaged by the authors, would cooperate closely with research-based therapy units and tumor registers. They would take on far-reaching advisory functions and would in principle be equipped with trend-setting competencies. For example, an ethics committee could recommend that a new concept, e.g., a combination therapy based on established treatments with "manageable" side effects, be directly applied in several institutions for broader clinical use. This could take place under strict, joint "supervision" by the ethics committee, the institutions that lead the therapy and the tumor registry. The continuous monitoring of patients—also using appropriate apps (see section on innovations)—would focus extensively and very promptly on side effects and tumor responses (see also below, comments on "Outcome Research" and tumor registries). Unforeseen events would be quickly registered and evaluated under the "supervision" of the Ethics Committee with regard to the further procedure in the study network. The evaluation of the new concept in a multi-center study would potentially have the advantage that larger patient numbers could be recruited relatively quickly and thus results could be recognized relatively early.

Another idea concerns "**Outcome Research**" and the collaboration of **tumor registries** with therapy institutions, if necessary, also with ethics committees (see above). After the introduction of new drugs, which are potentially always used in combination with radiation treatment, and other new therapeutic approaches, it would have to be generally reviewed as soon as possible in the future whether these would clearly prove to be more beneficial than the traditional forms of treatment in larger patient populations. The tumor registries would have to focus on better survival and/or lower risk of serious side effects.

"Outcome Research" with follow-up of many patients after cancer treatment including radiotherapy offers great potential in terms of generating evidence and progress (see above). In order to use this potential, however, it is necessary to have well-developed structures in view of the extensive tasks to be performed. When collecting and evaluating data, the range of topics would include clinical findings, histopathology, molecular biology of the tumor, imaging diagnostics, radiomics, liquid biopsies accompanying therapy, etc., as well as information concerning the survival time and quality of life of the individual patient (aftercare!) after completion of therapy. In the future, a very close cooperation between therapy institutions and the tumor registries should be made possible based on IT infrastructure. Correspondingly, better personnel equipment would have to be financed on both sides. It should be emphasized that radiooncology already systematically stores a large amount of patient- and treatment-related data in its therapy-controlling software platforms. To date, however, these data have not been included in the databases of tumor registers, which would be advantageous with regard to research into the efficiency and risk of side effects of certain radiation techniques, especially with regard to the quality of life of long-term survivors (cured former patients, e.g., prostate and breast cancer, etc.).

With the help of AI, the tumor registers would support and promote the optimization of therapies or the establishment of new treatment approaches in continuous exchange with therapists. This work would have to focus in particular on loco-regionally advanced and metastasized cancers. It could improve the efficiency in the generation of evidence if part of the money, which in prospective studies is sometimes of little use, were invested in the structures and staffing outlined above. Outcome research of the highest quality is in the interest of future generations of patients and of the cost bearers of the health care system.

The particularly complex problem of establishing future "**personalized therapies**" will not be discussed in detail here. However, one aspect can be seen: If, in future, screening and early detection (see above) enable the reliable visualization of early, non-metastatic tumors with imaging, local therapy methods, i.e., surgery and radiation treatment, will be in the foreground—in view of the number of patient treatments. These offer—either by surgical removal of the tumor or radiotherapeutic tumor destruction—a very high chance of cure in early stages of cancer with a low risk of permanent impairment (see above). For early-stage tumors, "personalized drug therapy," which is based on complex diagnostics, can therefore be largely dispensed with. This saves considerable costs. It should also be mentioned that local therapies in early stages are usually relatively inexpensive.

6 Concluding Remarks

Finally, it should be emphasized that the results of randomized studies should not necessarily be equated with high evidence and high "truth content." If there is considerable scope for misinterpretation, these should not be used as the sole basis for recommendations in guidelines. In "Interdisciplinary Tumor Conferences," it is not uncommon to argue as "automated" with reference to published studies. For example, in the case of publications with small patient numbers and improvements in median survival of only a few weeks, this is to be considered highly questionable.

In the future, too, doctors will be obliged to use their professional competence to assess the reality value of the available information precisely and critically. The own experience, the knowledge of treatment results of the own institution, especially epidemiological data of large tumor registers play an important role and are of great value. Only in this way, and increasingly supported by AI, will it be possible to make decisions that really benefit the individual patient. It should also be noted that the life circumstances of the individual patient must always be taken into account when determining a therapy concept. Corresponding detailed discussions with the patient (if necessary also with his relatives) have the highest importance and tradition in radiooncology!

In the generation of evidence in cancer medicine, a much more intensive **cooperation in the triangle of therapy institutions, tumor registries, and ethics committees** should take place in the future. The broader public should better understand the term “evidence” and related problematics. Appropriate information transfer through schools, cancer medicine institutions, public health care, etc., would be of great value in this context. The media, if they refrain from reporting irrelevant “sensations,” can also play an important role. It is a matter of strengthening a science-based “health awareness” of modern people in times in which research, which unfortunately frequently presents itself as dubious, is met with a partly justified and understandable mistrust. There should be a constant, honest, and responsible discourse between medicine, health policy, and society, which is not driven by superficial interests of doctors, scientists, pharmaceutical companies, equipment manufacturers, etc. The basic prerequisite for this is the collection and evaluation of data from clinical practice in order to obtain evidence for the improvement of existing therapeutic approaches. “If thousands of patients with diabetes, cancer or dementia made their data available, we could learn from them. Data can heal people” [19].

Improvements in the therapy of solid tumors in adults in advanced stages are urgently desired. The article shows conceivable future progress from the perspective of radiooncology with X-rays. Treatment with protons or heavy ions, which, according to experts, will in future account for about 15% of radiotherapy patients, is not taken into account here. For the future, however, we must keep an eye on the situation: **The real strategic opportunity to solve the cancer problem lies in prevention, but above all in screening and early detection with subsequent low-risk local therapy** (see above). For this reason, the latest initiative to promote research on these latter approaches by the Federal Ministry of Education and Research (speech by Minister Anja Karliczek on 19 May 2019, on the occasion of the presentation of the “Felix Burda Award”) as part of the “Decade against Cancer” is very welcome!

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Medicine und Senescence: An Example of Violation of Earth by Medical Progress

Hans P. Zenner

Abstract Fifty percent of the girls born in Germany in this century are expected to become 100 years old. Fifty percent of the boys become well over 90 years old. Such a high age expectance in Germany and in other nations is substantially related to the success of modern medicine. Naturally, this elaborate type of modern medicine consumes considerable resources of the Earth so that the enormous expense of successful modern medicine has contributed significantly to the violation of the Earth. In an ethical consideration, one can ethically justify the use of resources of the Earth for an evidence-based medicine. In the absence of evidence, however, health care's indirect injury to the Earth must be questioned. This notwithstanding missing evidence is necessarily associated with misuse and oversupply. Both medical misuse and oversupply may represent an unjustifiable indirect violation of the earth contributing to an ethically not justified overuse of Earth's resources.

Keywords High age · Multi-morbidity · Resource use · Medical supply · Modern medicine · Fourth age

1 Introduction

Fifty percent of the girls born in Germany in this century are expected to become 100 years old. Fifty percent of the boys become well over 90 years old [4, 17]. Thus, they will be up to 40 years older than the generation of sixty-year-olds, who with their age of sixty have reached the age, which in medicine is often associated with

[1] According to Leopoldina [11] findings based on research into the course of cognitive performance, of dependency as well as wellbeing may even lay in the future the demarcation of a "fifth age" close. This novel view assumes in that changes at different levels (biological, psychological) in the extremely advanced time corridor of the individual life represent not so much of the chronological age, but are determined by the distance from death (Distance-to-Death Research; Terminal Decline or Terminal Drop. Cf. (Gerstorf et al. 2010,2013).

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the terms "old" or "presby" (Greek for old). Of course, the average morbidity and the incidence of diseases is not the same for sixty- and for one-hundred-year-olds (German National Mikrozensus 2013) [5–7, 20] so that a subdivision into a third and fourth age was proposed for this age range from 60 to more than 100 years [10]. It is not uncommon to speak of the fourth age[1] from the age of 80, but the trend of demarcation between the third and fourth age may move this demarcation toward ninety years, especially if the age is taken, at which 50% of the contemporaries are dead [11]. Based on the demarcation at the age of eighty, 4.5 million people (5.4% of the population) currently live in Germany at the fourth age (Destatis 2013) [10].

2 Problem

The fact that such a high age may be achieved in Germany and in other nations is substantially related to the success of modern medicine, including the control of infectious diseases, the development of modern drugs and surgical procedures, as well as modern medical devices. Specifically, progress in cardiology and oncology has contributed [14, 16]. Naturally, this elaborate type of modern medicine consumes considerable resources of the Earth so that the enormous expense of successful modern medicine has contributed significantly to the violation of the Earth due to the currently dominant methods of resource provision.[2]

In an ethical consideration, one can ethically justify the use of resources of the Earth for an evidence-based adequate therapy, because the well-being of man in connection with the restoration of human dignity and autonomy justify the use of resources of the Earth. Such a consideration is accepted as far as evidence-based medicine[3] is concerned. In the absence of evidence, however, medicine's indirect injury to the Earth must be questioned. This notwithstanding, missing evidence is necessarily associated with misuse and oversupply. Both medical misuse and oversupply may represent an unjustifiable indirect violation of the Earth, contributing to an ethically not justified overuse of Earth's resources.

In addition to the high incidence of diseases and the resulting high morbidity, a high level of multimorbidity is characteristic of individuals in the fourth age of life [1, 23]. In addition, there is empirical evidence that numerous diseases—such as carcinoma disorders—biologically behave differently at this age than at a younger age. Moreover, frailty may occur [2].

At the same time, sufficient prospective clinical studies on this altered disease behavior in the fourth age and thus a scientifically based clinical evidence for the above-mentioned empirical medical hypothesis is often missing. At the same time, there is no evidence for the age-specific efficacy of a large number of therapeutic methods, including medications, that has been demonstrated by prospective clinical studies. Usually, prospective studies on the efficacy and adverse events of drugs and

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[2] These methods, and approaches how to replace them are addressed in other papers of this book.

[3] http://www.ebm-netzwerk.de/was-istebm/grundbegriffe/definitionen.

other therapeutics have been performed on probands of the second age (18–59 years) and not of the fourth age. Based on the hypothesis that the behavior of diseases at the fourth age may be significantly different from that of the second age, the results of prospective controlled second age studies cannot be unequivocally transferred to the fourth age (cf. [12, 21]). Thus, the necessary scientifically based clinical therapy evidence may often be lacking.

Multimorbidity of the fourth age necessarily leads to pragmatic therapy with multiple component interventions such as polypharmacy. However, the above-mentioned prospective controlled studies of the second age are generally carried out in a mono-therapeutic setting and, for the most part, do not provide sufficient information for the efficacy and tolerability of multiple-component interventions. As a rule, sufficient clinical evidence is thus lacking for the regular pragmatic therapy with multicomponent interventions.

In addition, the elderly may combine therapy with other goals [8], see also[4]) than patients of the second age cohort. At the center of the goals of the very old are symptom relief, quality of life despite complaints, the safeguarding and, if necessary, the restoration of self-employment, and the delay in moving to a nursing home [19]. On the other hand, there is often no desire for life extension, especially when it comes to diseases with significant burdens [11]. Experience has shown that very old people with debilitating illnesses can be cited, for example, as saying “I have lived my life” or “that is no longer life.”

The objective of patients of the fourth age deviating from those of the second age corresponds to a striking asymmetry between subjective self-assessment of a disease in comparison with the objective assessment by the physician. They often may fall apart significantly. The self-assessment of subjective health is usually higher than the objective evaluation [25]. In spite of a physician´s objective and severe concern (e.g., due to a cardiac disease), patients of the fourth age often do not feel that they are subjectively ill or impaired. In connection with the above-mentioned goal of quality of life despite the discomfort, this subjective assessment deviating from that of the physician is decisive for well-being and life satisfaction. This subjective assessment, which deviates from the objective state, naturally has considerable influences on the treatment because it is the patient who ultimately has to give his informed consent.

Using the Disablement-Process-Modell this situation can be partly described with the epidemiological concept of functional health [22]. Functional health describes the ability to fulfill everyday activities (ADL, Activities of Daily Living) in order to participate in social life. This right to participate is emphasized by the German Social Code (Sozialgesetzbuch, SGB). Thus, in order to be able to meet high age requirements and the right to participate despite illness, social barriers as a consequence of illness must be recognized and minimized. As an objective treatment goal, a social withdrawal must be avoided.

If one considers those diseases of the very old, which at the same time massively impede the fulfillment of age requirements, disturb social participation, create social

[4] Cf. Berliner Altersstudie (BASE): https://www.baseberlin.mpg.de/de.

barriers and thus lead to social retreat, the often mentioned cardiovascular, metabolic and psychiatric diseases[5] are less often the underlying reason than other disorders.

A significantly higher impact has hearing disorders, visual disturbances, dizziness/vertigo and immobility as well as the comorbidity of several or all of these disease groups [9, 11, 14, 24]. Dizziness promotes immobility and may ultimately lead to falls resulting in fractures and in a further immobility increase. As already mentioned it is typical for very old people that they may be affected by several of the named disease groups. In particular, they may be characterized as multisensory diseased when suffering at the same time from a hearing disorder, visual disturbance, and dizziness [11].

Furthermore, functional health is also dependent on the social and physical-spatial environment, on supporting relatives and on a barrier-free living and living environment. Social losses, such as the loss of a partner or the loss of a child, as they are significantly more common at the fourth age, are also more influential than in the first three age groups.

As mentioned at the beginning, a lack of evidence in medicine is necessarily associated with misuse and oversupply. As shown here, the lack of a scientific evidence basis in geriatric medicine is significant. At the same time, the cohort of the elderly is increasing. Misuse and oversupply are ethically unjustifiable because (i) they can harm patients. Furthermore, (ii) the above-demonstrated missing evidence of pathophysiology of diseases and the corresponding lack of evidence of both monotherapies and polypragmatic therapies leads to the hypothesis that important approaches to the presently available geriatric medicine may indirectly contribute to avoidable violations of the Earth. Naturally, these considerations also apply to the first to third ages, however to a much lesser extent.

3 Recommendations

In his appraisals of 2000 and 2009, the German council of experts for health care development [15] made aware that the adequate care of chronic and multimorbide patients is one of the most urgent tasks in the health system. This leads to recommendations for evidence-based geriatric medicine, as they were partly also submitted by the German National Academy of Sciences [11]:

- Studies on the course of diseases in the elderly (for example, of tumors)
- Functional health studies
- Studies on treatment goals, detection of individual goals of elderly

[5] According to Schäfer et al. (2012), and Leopoldina [11] certain illness constellations occur especially often. Studies show accumulation of anxiety, depression, somatoform disorders as well as pain in women, while men more likely suffer from cardiovascular (e.g., heart failure) and metabolic disorders (e.g., diabetes mellitus). See also: (Barnard et al. 2014; Abramson et al. 2014; Schiattarella et al. 2014; Behrman and Ebmeier 2014; Fratiglioni and Qiu 2009).

- Pragmatic studies with multiple component interventions (complex interventions) and observational studies
- Adaptation of statistical methods to multi-component interventions
- Recognition of adapted statistical methods in regulatory proceedings (significance, power, effect size)
- Studies on the efficacy evidence of medical devices in multisensory diseased elderly
- Hearing aids
- Equilibrium aids
- Mobility aids
- Visual aids
- Studies on the evidence of exercise treatment in multisensory diseased elderly
- Investigations on the role of smart home products in multisensory diseased elderly.

4 German Translatiion

4.1 Einleitung

Fünfzig Prozent der in diesem Jahrhundert in Deutschland geborenen Mädchen werden voraussichtlich 100 Jahre alt. Fünfzig Prozent der Jungen werden deutlich über 90 Jahre alt. Sie werden also bis zu 40 Jahre älter sein als die Generation von Sechzigjährigen, die mit sechzig Jahren ein Alter erreicht haben, welches in der Medizin häufig mit dem Begriff „alt “ oder „presby “ (griechisch für alt) verbunden wird. Die durchschnittliche Morbidität und die Inzidenz von Krankheiten ist freilich für die sechzig- bis über Einhundertjährigen nicht gleich, so dass für diese Alters-Spanne von 60 bis über 100 Jahre eine Unterteilung in ein drittes und viertes Alter vorgeschlagen wurde. Nicht selten spricht man vom vierten Alter ab dem achtzigsten Lebensjahr, jedoch geht die Tendenz der Grenzziehung zwischen drittem und viertem Alter in Richtung neunzig Jahre. Ausgehend von der Grenzziehung mit dem achtzigsten Lebensjahr leben in Deutschland gegenwärtig 4.5 Millionen Menschen im vierten Alter (5,4 Prozent der Bevölkerung).

4.2 Problem

Die Tatsache, dass ein derart hohes Lebensalter in Deutschland und anderen Nationen erreicht wird, steht wesentlich mit dem Erfolg der modernen Medizin einschließlich der Bekämpfung von Infektionskrankheiten, der Entwicklung von modernen Arzneimitteln und operativen Behandlungsverfahren sowie von modernen Medizinprodukten in Beziehung. Naturgemäß konsumiert diese aufwändige Art der modernen Medizin erhebliche Ressourcen der Erde, so dass der enorme

Aufwand der erfolgreichen modernen Medizin auf Grund der bis gegenwärtig dominierenden Verfahren der Ressourcenbereitstellung[6] maßgeblich zur Verletzung der Erde beigetragen hat.

Bei einer ethischen Abwägung wird man eine Ressourcennutzung der Erde für eine evidenzbasierte adäquate Therapie grundsätzlich ethisch rechtfertigen können, denn das Wohl des Menschen in Verbindung mit der Wiederherstellung von Menschenwürde und Autonomie rechtfertigen die Ressourcennutzung der Erde. Man findet bei einer derartigen Abwägung Zustimmung, soweit es sich um evidenzbasierte Medizin handelt. Bei fehlender Evidenz muss jedoch die mittelbare Verletzung der Erde durch die Medizin im Einzelnen hinterfragt werden. Denn fehlende Evidenz ist notwendigerweise mit Fehlversorgung und Überversorgung verbunden. Sowohl Fehlversorgung als auch Überversorgung bedeuten eine nicht zu rechtfertigende mittelbare Verletzung der Erde durch Übernutzung und Fehlnutzung der Ressourcen der Erde.

Für die Menschen des vierten Lebensalters charakteristisch ist neben der hohen Inzidenz von Krankheiten und daraus resultierender Morbidität eine gleichzeitige hohe Multimorbidität. Zudem gibt es erfahrungsmedizinische empirische Hinweise, dass zahlreiche Erkrankungen -wie beispielsweise Carcinom-Erkrankungen- sich in diesem Alter biologisch anders verhalten als in jüngerem Alter. Zugleich fehlen ausreichende prospektive klinische Studien über dieses veränderte Krankheitsverhalten im vierten Alter und damit eine wissenschaftlich basierte klinische Evidenz für die o.g. erfahrungsmedizinische Hypothese.

Zugleich fehlt aber auch eine durch prospektive klinische Studien belegte Evidenz für die altersspezifische Wirksamkeit zahlreicher Therapieverfahren einschließlich von Medikamenten. Üblicherweise sind prospektive Studien zur Wirksamkeit und zu den Nebenwirkungen von Medikamenten bei Personen des zweiten Alters (18–59 Jahre) und nicht des vierten Lebensalters durchgeführt worden. Ausgehend von der Hypothese, dass sich das Verhalten von Krankheiten im vierten Alter SICH streichen sich von dem des im zweiten Alter signifikant unterscheidet, lassen sich die Ergebnisse prospektiver kontrollierter Studien des zweiten Alters nicht zweifelsfrei auf das vierte Alter übertragen. Damit fehlt häufig die notwendige wissenschaftlich basierte klinische Therapie-Evidenz.

Die Multimorbidität des vierten Lebensalters führt notwendigerweise zu einer pragmatischen Therapie mit Mehrfachkomponenten-Interventionen wie z.B. Polypharmazie. Die bereits erwähnten prospektiv kontrollierten Studien des zweiten Lebensalters werden jedoch in der Regel monotherapeutisch durchgeführt und geben weit überwiegend keine ausreichenden Hinweise für die Wirksamkeit und Verträglichkeit von Mehrfachkomponenten-Interventionen. Damit fehlt für die regelmäßig durchgeführte pragmatische Therapie mit Mehrfachkomponenten-Interventionen in der Regel eine ausreichende klinische Evidenz.

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[6] Die Ersatz derartiger Verfahren durch die Erde schonende Verfahren wir in anderen Arbeiten dieses Bandes angesprochen.

Hinzu kommt, dass Hochbetagte mit einer Therapie andere Ziele verbinden können, als Patienten der zweiten Alterskohorte. Im Zentrum der Ziele Hochbetagter stehen nämlich Symptomlinderung, Lebensqualität trotz Beschwerden, die Sicherung und gegebenenfalls Wiederherstellung von Selbständigkeit sowie die Verzögerung eines Umzuges in ein Pflegeheim. Hingegen besteht nicht selten kein Wunsch nach Lebensverlängerung, insbesondere wenn es sich um belastende Erkrankungen handelt. Erfahrungsgemäß können Hochbetagte mit belastenden Erkrankungen beispielsweise zitiert werden mit „ich habe mein Leben gelebt“ oder „das ist kein Leben mehr“.

Den von Betroffenen des zweiten Alter abweichenden Zielvorstellungen von Patienten des vierten Alters entspricht eine auffällige Asymmetrie zwischen subjektiver Selbsteinschätzung der Erkrankung im Vergleich mit der objektiven Beurteilung durch den Arzt. Sie fallen oftmals deutlich auseinander. Die Selbsteinschätzung der subjektiven Gesundheit ist in der Regel höher. Trotz objektiver schwerer Betroffenheit empfinden sich Patienten des vierten Alters häufig subjektiv nicht als krank oder beeinträchtigt. In Verbindung mit dem oben genannten Ziel von Lebensqualität trotz Beschwerden, ist diese subjektive vom Arzt abweichende Einschätzung maßgeblich für Wohlbefinden und Lebenszufriedenheit. Diese vom objektiven Zustand abweichende subjektive Einschätzung hat naturgemäß erhebliche Auswirkungen auf die Behandlung, zu der der Patient letztlich sein informed consent (Einverständnis) geben muss.

Diese Situation kann mit dem epidemiologischen Begriff der funktionalen Gesundheit teilweise beschrieben werden. Funktionale Gesundheit beschreibt die Fähigkeit, Alltagsanforderungen (ADL, **A**ctivities of **D**aily **L**iving) zu erfüllen, um auf diese Weise am sozialen Leben teilzuhaben. Das Recht auf Teilhabe betont auch das deutsche Sozialgesetzbuch. Um trotz Erkrankung Altersanforderungen und das Recht auf Teilhabe erfüllen zu können, müssen soziale Barrieren als Folge von Krankheiten erkannt und beseitigt werden. Als objektives Behandlungsziel muss ein sozialer Rückzug vermieden werden.

Betrachtet man unter den Gesichtspunkten der Ziele Hochbetagter die Erkrankungen, die zugleich die Erfüllung von Altersanforderungen massiv beeinträchtigen, die soziale Teilhabe stören, soziale Barrieren errichten und auf diese Weise zum sozialen Rückzug führen können, so trifft man weniger häufig auf kardiovaskuläre oder dementielle Erkrankungen. Signifikant häufiger sind Hörstörungen, Sehstörungen, Schwindel und Immobilität sowie die Komorbidität mehrerer oder aller dieser Krankheitsgruppen. Der Schwindel fördert die Immobilität und kann letztlich zu Stürzen mit Frakturen und Steigerung der Immobilität führen. Charakteristisch für Hochbetagte ist es, dass sie von mehreren der genannten Krankheitsgruppen betroffen sein können und insbesondere multisensorisch gleichzeitig an einer Hörstörung, Sehstörung und Schwindel leiden können.

Zugleich ist die funktionale Gesundheit aber auch abhängig von sozialer und physisch-räumlicher Umwelt, von unterstützenden Angehörigen sowie einem barrierearmen Wohn- und Lebensumfeld. Ebenfalls Einfluss haben soziale Verluste wie der Verlust des Lebenspartners oder der Verlust eines Kindes, wie sie im vierten Alter deutlich häufiger vorkommen, als in den Gruppen des ersten bis dritten Alters.

Wie Eingangs bereits erwähnt, ist eine fehlende Evidenz in der Medizin notwendigerweise mit Fehlversorgung und Überversorgung verbunden. Wie hier dargestellt, spielt die fehlende Evidenzbasierung in der Altersmedizin eine große Rolle. Zugleich nimmt die Kohorte der Hochbetagten zu. Fehlversorgung als auch Überversorgung sind ethisch nicht zu rechtfertigen, denn (i) sie können den Menschen schädigen. (ii) Die oben skizzierte, für das vierte Alter fehlende Evidenz von Pathophysiologie von Erkrankungen und korrespondierender fehlender Evidenz sowohl von Monotherapien wie auch unvermeidbarer polypragmatischer Therapien führt daher notwendigerweise zur Hypothese, dass dies besonders in der Altersmedizin mittelbar zu einer ethisch nicht zu rechtfertigenden Verletzung der Erde beiträgt. Naturgemäß gelten diese Überlegungen auch für das erste bis dritte Alter, wenngleich hier in einem deutlich geringeren Maß von fehlender Evidenz auszugehen ist.

4.3 Empfehlungen

Daraus ergeben sich Empfehlungen zu einer evidenzbasierten Altersmedizin, wie sie teilweise auch von der Deutschen Nationalen Akademie der Wissenschaften [11] abgegeben wurden:

- Studien zum Krankheitsverlauf (z.B. von Tumoren)
- Studien zur funktionalen Gesundheit
- Studien zu Behandlungszielen, zur Erkennung von Individualzielen
- Pragmatische Studien mit Mehrfachkomponenteninterventionen (komplexe Interventionen) sowie Beobachtungsstudien
- Anpassung statistischer Methoden an Mehrfachkomponenteninterventionen
- Anerkennung angepasster statistischer Methoden bei behördlichen Verfahren
- Studien zur Evidenz von Medizinprodukten bei multisensorisch erkrankten Hochbetagten
- Hörhilfen
- Gleichgewichtshilfen
- Gehhilfen
- Sehhilfen
- Studien zur Evidenz von Übungsbehandlungen bei multisensorisch erkrankten Hochbetagten
- Untersuchungen zur Rolle von *smart home*-Produkten bei multisensorisch erkrankten Hochbetagten

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Epigenetics Won't Do Miracles. Some Sobering Remarks in Response to Professor Johannes Huber

Konrad Oexle

Abstract In some quarters it is expected that epigenetics will translate desirable ethical attitudes into the biological disposition of a new human being that, thus, better fits into its fragile environment. Here, I confront such high flying expectations with the reality of research findings in epigenetics. This includes the fact that epigenetic reprogramming in each generation largely inhibits epigenetic information transmission so that true transgenerational epigenetic inheritance in mammals is an exception and, in fact, still not proven with sufficient evidence.

Keywords Epigenetics · Transgenerational inheritance · Germline · Reprogramming · Metastable epialleles

1 Huber's Expectations

Epigenetics is a promising field [5, 16]. As such, it has raised far-reaching expectations. The prominent Austrian gynecologist and endocrinologist Johannes Huber, for instance, provided a series of popular books, lectures, and interviews in which he addressed epigenetics and claimed that "love can be inherited." "Mothers and fathers have it far more in their hands than previously thought to influence a healthy and happy future for their offspring through a conscious life." "By epigenetics the training (of neurons) can be transmitted to the next generation," he states, and that "the child will inherit this further to its own children" so that epigenetics will allow us to create the new human being, the "homo sapiens sapiens," who will be sufficiently unselfish and "altruistic" in order to fit into the stressed environment of a crowded planet [9–11]. Even "the faith in God lies in the epigenome," according to Huber [11]. He proposes these and other speculative and partly esoteric theses with the attitude of a down-to-earth scientist, thus inspiring hopes in his audience that epigenetics might be the pathway on which mankind can overcome the ecological crisis.

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2 Review of Research Findings in Epigenetics

Huber's expectations touch on magical thinking. Here, I outline some basic concepts of epigenetics and review recent developments concerning transgenerational epigenetic inheritance in mammals including humans. As I will show, the developments suggest a rather sober and skeptical stance [1, 3, 8]. The following points will be emphasized.

(i) Epigenetics primarily means gene regulation.
(ii) Epigenetic mechanisms and their potential for adaptation to changing environments are encoded genetically.
(iii) In mammals and other animals, somatic cells which are subject to environmental influence do not turn into germ cells.
(iv) Moreover, epigenetic reprogramming in each generation largely inhibits epigenetic information transmission via the germline.
(v) Transgenerational epigenetic inheritance in mammals is an exception and still not proven with sufficient evidence.

Maintenance and directed modification of gene activity states underlie the stability and canalized plasticity, respectively, of cells and tissues. "Epigenetics" [16] is the science that examines these states. (As usual in the natural sciences, the discrimination between the science and its object is blurred so that "epigenetics" also is the name of the examined phenomenon.) Thus, epigenetics concerns the regulation of the orchestrated organismal development and of the many highly differentiated cell types according to the inherited genetic information. This regulation differs in time and space from cell type to cell type so that each cell type has its specific "epigenome." Characteristic aspects of the epigenome do not substantially change if the cell type is stable across cell divisions. Differentiation of cells into another type comes along with specific changes of their regulatory epigenetic states. Since the epigenetic regulation of permanence or differentiation of cells is largely determined genetically, epigenetics is the maid of genetics.

Organisms are disposed to react, to adapt, and to learn from environmental conditions. These conditions may affect the epigenetic states of cells. Therefore, epigenomes do integrate environmental information according to genetically determined schemes. Of note, this is not exceptional. Nearly any biochemical process in the organism integrates environmental information to some extent and via some more or less indirect mediation. Just consider an enzymatic turnover process, for instance, whose turnover rate adapts biochemically to the concentration of its environmental substrate.

The generational sequence of individual organisms is the upshot of a sequence of cells. Genetic information runs through this 'germline' from germ cell to germ cell (Fig. 1). On the germline 'stand' the mortal somata, i.e., the individual organisms that are necessary evolutionarily to help the germ cells from the spot, to survive, and to unite in case of sexual reproduction. Via the germline, epigenetic states may have a transgenerational impact as has been shown in plants, roundworms, and fruit flies where epigenetic states may affect many consecutive generations. Since cellular epigenetic processes react to environmental influences, this amounts to the inheritance of acquired traits. Whether such transgenerational epigenetic inheritance also exists in mammals and humans, especially, has attracted considerable interest in recent years.

DNA methylation is the paradigmatic epigenetic modification. Contrary to a prevalent assumption, epigenetics is not limited to DNA methylation, however. There are other DNA modifications besides the typical methylation of cytosine, and there are various steering modifications of the DNA-packaging proteins ("histones"). Modifications of these histones may function, for instance, by influencing the access of regulating proteins ("transcription factors"). The direct binding of the transcription factors to DNA depends on DNA methylation, but they may also control methylation, thus being not only "readers" but also "writers" of epigenetic information. It would be erroneous, therefore, to reduce epigenetics to DNA methylation. In general, the key pathways in epigenetics include transcription factors, architecture, and modifications of the chromatin (= DNA plus packaging proteins), non-coding RNAs, and prions [3].

Environmental conditions during the lifetime of an organism are reflected in the epigenetic patterns of its cells. For example, overeating or the smoking habits of an individual leave traces in the DNA methylation profile of white blood cells. However, in animals such as mammals, flies, and roundworms, somatic cells do not enter the germline ("Weismann barrier", [19]) so that they cannot inherit their epigenetic information about environmental conditions to the next organismal generation via cell division. Thus, for transgenerational epigenetic inheritance to take place, either the environmental condition must reach the germ cells directly or the exposed somatic cells must release a messenger that modulates the germ cells' epigenomes.

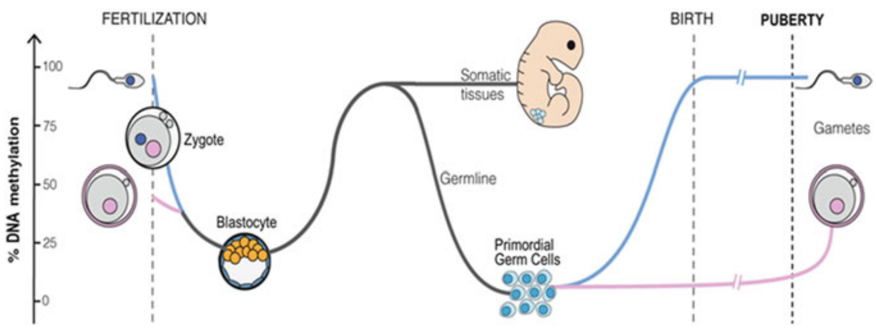

Fig. 1 Epigenetic reprogramming during prenatal development in mammals with two major steps of DNA methylation erasure. Soon after fertilization, the specific methylation patterns of the gametes (sperm and egg cell) are largely removed, except for some regions such as genes with parental imprinting. For the organogenesis in the embryo, specific methylation patterns are re-established thereafter. In primordial germ cells of the fetus, the DNA methylation is erased again to be re-established thereafter in the gametes according to the sex of the fetus (modified with simplification from [17])

In mammals, the corresponding hypothetical mechanisms still are largely unresolved [1, 3, 8].

Obviously, however, mammals do transmit information from one generation to the next, independent of the DNA sequence inherited via the germline. Transmission occurs by the shaping of the ecological niche or by cultural trends, for instance [5, 8]. Besides humans, many animal species exhibit some level of education and culture. Even flies display cultural copying [4]. Any such non-genetic transfer of information could be regarded as "epi"-genetic inheritance if a rather relaxed definition of the term was applied. However, the term would become inflationary thereby and thus lose its discriminatory power. Transgenerational epigenetic inheritance according to its prevailing definition requires non-genetic inheritance via the germline [1, 8].

The discrimination can get rather subtle, though, as evidenced by the process discussed in [5], for instance: In female pups of highly caring rat mothers the genes of sex hormone receptors in the brain show low levels of promoter DNA methylation, while female pups deprived of such care show high levels of methylation and silencing of these genes. Becoming mothers themselves, the pups with active sex hormone receptors will then also be caring mothers, while the pups of uncaring mothers will be uncaring mothers. This finding probably has triggered Huber's thesis that "love can be inherited" epigenetically [9, 10]. However, it is not a true instance of epigenetic inheritance because the epigenetic marks are not transmitted via the germline but are reinstalled in each generation as a consequence of the maternal behavior. The epigenetic marks (promotor methylation) do not themselves transmit the behavioral information to the next generation but are the molecular consequence of educational transmission, being reinstalled in each generation anew.

Various environmental exposures in early life (including nutritional factors, traumata, and "endocrine disruptors", that is, chemicals that interfere with hormonal systems) have been claimed to cause transgenerational responses in mouse and rat models. However, these studies still need to be confirmed [8]. And some have been challenged by others who showed that germ cell modifications are erased upon reprogramming in the next generation [2, 12, 18] or demonstrated that nutrition has a minor effect on the variance of DNA methylation in sperm cells [15]. Moreover, if the observed differences of germ cell DNA between exposed and unexposed animals are small, most of their germ cells must be identical at the epigenetic position in question because each germ cell carries only one genome which either has the epigenetic marker at that position or not. Then, however, it is difficult to explain a substantial difference in the phenotype (appearance, behavior) between the offspring of exposed and the offspring of unexposed because each offspring has been begotten by one germ cell [1].

Recently, Kazachenta et al. [13] systematically analyzed the mouse genome for the inheritance of local DNA methylation patterns, which qualify as "metastable epialleles," that is, as variants of a gene that are variably expressed in genetically identical individuals due to epigenetic modifications. They found that most of these patterns are reprogrammed in the offspring's organism and concluded that their "findings raise questions about the generalizability of non-genetic inheritance at metastable epialleles and suggest that variable methylation can be reprogrammed and reconstructed across generations in the absence of a memory of parental state by a process that may depend on the genetic context of the variably modified locus."

Indeed, if parents and children share the same abnormal epigenetic pattern, this does not prove epigenetic inheritance. Co-segregation of a genetic mutation may generate that pattern as a "secondary epimutation" in each generation anew. Such constellations have been described in human genetic diseases including inborn errors of metabolism and familial colon cancer [6, 7]. To find the causative genetic mutation may be tricky since it may not reside in the same gene as the secondary epimutation. Instead, it may be located in a neighboring gene, for instance, where it generates aberrant read-through transcription. If the read-through transcription reaches the gene in question, it may affect the DNA methylation there, thus causing the secondary epimutation of that gene (ibd.). Even germ cells may show the secondary epimutation, making the differentiation from primary epigenetic variation rather difficult (ibd.).

Thus, transgenerational epigenetic inheritance in mammals is hard to prove. Horsthemke [8] recently proposed a roadmap to do so. Besides secondary epimutations, ecological or educational/cultural inheritance has to be excluded. Moreover, it is necessary to set apart prenatal exposure of the unborn ("fetal programming") and of the germ cells of the unborn ("intergenerational inheritance") which may affect the generation of the children and grandchildren, respectively. True transgenerational epigenetic inheritance can still be observed when the transmitting germ cells never could have been subject to the environmental exposure, that is, in the grandchildren of an exposed male or in the grand-grandchildren of an exposed pregnant female. Furthermore, the epigenetic factor (e.g., the specific DNA methylation) must be identified in the germ cells while contaminations by somatic cells need to be avoided. Finally, the proof must be completed by removing and re-adding the epigenetic factor to the germ cells while showing that the inherited phenotype disappears and re-appears, respectively.

Obviously, the last step of that roadmap can be taken in animal models only. There are reports on transgenerational epigenetic inheritance in humans, especially in connection with malnutrition (reviewed in [14]). However, the conditions of investigation are unreliable in comparison to the rodent model. Besides the limitations of experimental manipulation, the observation time is much longer due to the much higher reproductive age so that studies in humans usually can be retrospective only.

Important questions related to the molecular mechanisms of how the somatically acquired information should reach the germ cells and whether the corresponding factor is (or needs to be) translated there into (another) epigenetic code. It is assumed that non-coding RNA molecules are mediators that circulate in the blood and act on the germ cells in the gonads. However, the details are still unclear [1, 3, 8]. Moreover, the question arises as to how specific epigenetically inherited information would be: "How much information is transmitted by the germline—how coarse-grained is the representation of the world provided by parents to their children?" [3].

Acquired information that enters transgenerational epigenetic inheritance has to overcome epigenetic reprogramming in early embryogenesis and in germ cell development (see Fig. 1). Leading scientists [1, 8] remain skeptical as to the relevance of transgenerational epigenetic inheritance in humans. In fact, in mammals whose generation time is long, epigenetic inheritance that extends over several generations is not to be expected from an evolutionist's point of view. If it comes up to its presumed evolutionary function, i.e., adaptation to changing environmental conditions, it should not last longer than the half-life of these conditions.

3 Conclusion

To summarize and to come back to Professor Huber, it is to be emphasized that the current state of knowledge in epigenetics does not support his claim that "mothers and fathers have it far more in their hands than previously thought to influence a healthy and happy future for their offspring through a conscious life." [9, 10] Instead of unwarranted speculations, he should realize that "at present there is no evidence for a direct effect of culture on the epigenome" [8].

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Towards a New Enlightenment

New Enlightenment Towards Methodological Cosmopolitanism and Cosmopolitan Democracy

Andreas Klinke

Abstract We have entered a new age called the Anthropocene because human behaviour and action have deeply and irreversibly influenced the planet. Fundamental global transformations are engulfing the natural and social world. We live in a world where there are many unmet needs in the governance of global socio-material systems affected by these transformations. I argue that this unmet governance needs justify the resurrection of the Enlightenment with special attention to a view instructed by methodological cosmopolitanism. A change in emphasis to methodological cosmopolitanism, away from methodological nationalism, will stimulate social sciences and philosophy to become an independent global force with the power and authority to challenge the pigeonholed thinking characteristic of the nation-state paradigm and construct a new cosmopolitan democratic organization of social being, both theoretically and practically. To this end, this book chapter substantiates three major dimensions of methodological cosmopolitanism that are indispensable to understand and meet the global challenges our Earth is facing in the age of the Anthropocene: the rise of methodological cosmopolitanism as a new paradigm, the cosmopolitization of public understanding, and the venture towards cosmopolitan democracy conveyed by new epistemological, ontological and teleological authorities.

Keywords New Enlightenment · Methodological cosmopolitanism · Public understanding · Cosmopolitan democracy · Epistemological authority · Ontological authority · Teleological authority

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1 Introduction

Many scholars argue that we live in a new geological epoch—the Anthropocene—in which human behaviour and action have become the prevailing factors that have deeply and irreversibly influenced the planet. The deep and irreversible human influence on the Earth gained momentum through the Columbian exchange, an early form of globalization at the dawn of the modern era in the sixteenth century, and has grown dramatically since the 1950s. Undoubtedly, we have entered "A Global Age" beyond modernity [3] in which the world has become a highly interconnected and interdependent global sphere where human fates are interlocked in a complex system of intersecting and multi-layered interactions. Globalization has become associated with a multiplicity of global economic, political, cultural and environmental processes and developments. It has created transboundary and intercontinental networks, worldwide exchange and dependent relationships between continents, countries and people, it has geographically dispersed spheres of influence and power, it has reshaped individual lives and the organization of social being, and it has produced "overlapping communities of fate" ([52]: x). For decades, we have been observing the globalization of environmental problems; the scale and impact of global environmental change has been dramatically aggravated, with Climate Change, loss of biodiversity, deforestation, water crises, air pollution, chemical exposure, marine pollution, etc. Although there is an environmental global governance complex consisting of multiple agreements and international institutions, its fragmentariness, lack of coordination, inefficiency and ineffectiveness have undermined its authority, legitimation and capacity to sustainably govern global environmental problems [11–13, 52, 95].

Globalization seems to be destined to violate the Earth and is transforming our social being in permanent ways: Economic, political, cultural and ecological globalization has brought uncertainty, insecurity and injustice for some while others benefit and profit from it. This has increased global interconnectedness and interdependency and created an economic oligarchism. Growing social and economic inequality, social and political polarization, re-nationalization, unilateralism, and new populism have also become more prevalent. Joseph E. Stiglitz [85], Nobel Prize winner in economic science, argues that the discontent arising from the effects of economic globalization and the failure to curtail its negative impact, particularly social inequality and injustice, has played into the hands of populist and nationalist politics. Globalization and its effects intensify polarizations and the divide between those who favour a nationalist backlash and want to reverse globalization and those who argue for a democratic transformation at the transnational and global level and for cosmopolitan governance and democracy.

In the wake of this tension, humanity is faced with an uncertainty that is increasingly complex, imponderable and ambiguous in the context of dramatic global environmental change, new technological developments (digitalization and AI) and other global risks, whether that be terrorism, financial and economic crises, increasing social inequality and injustice, global migration, pandemics, human trafficking, corruption, the supposed anti-climax of liberal democracy, the rise of new populism and extremism, or the emergence of post-facticity and post-truth. Humans share a common destiny in that the uncertainties and global risks we face are nested in a global web of interconnectedness and interdependence that leads to the "shrinking of distances between most facets of human co-existence" ([16]: 1). For example, environmental exploitation and interrelated lifestyles as well as the organization of social being in one part of the world have a bearing and impact on locations and people in other parts of the world. New environmental conditions brought about by global environmental change and degradation driven by the capitalist principles of competition and profit maximization define our social being in the late twentieth and early twenty-first centuries and herald an epochal transformation significantly different from all past human experience. Ulrich Beck [9] speaks of a "Metamorphosis of the World" to describe the fundamental global transformation that is engulfing the natural and social world. These new dynamics, processes and forces are inducing new challenges for traditional structures and orders as society, politics and nature are shifting from established patterns to uncertain system behaviour and new norms and values. As Beck writes, "the very idea of controllability, certainty or security—which is so fundamental in the first modernity—collapses" (2010: 218). I argue that we live in a world where there is much unmet need in the governance of global socio-material systems, which are neither solely physical nor solely social or political because they inevitably interrelate the natural and social world in a planetary whole (cf. [86]). Global socio-material systems consist of multiple dimensions, networks, relations and layers encompassing natural, social, political and cultural aspects and global processes that entail a unique and growing complexity, interconnectedness, interdependency, imponderability and uncertainty. They are at risk on an unprecedented scale. Global socio-material systems remind us of the ontological essentials that human individuals are all members of a planetary community and have an obligation to care for our common interests. I argue that unmet needs in regard to the governance of global socio-material systems justify the resurrection of the Enlightenment, and I pay special attention to a cosmopolitan view.[1]

Looking at the values and beliefs of the classical Enlightenment, I argue that in light of contemporary globalization, we need to renew Immanuel Kant's cosmopolitanism politically and socially. Contextualizing epistemology and human action to affect global socio-material systems, common goods and global risks is key if we are to recognize the interconnectedness of the local and global. A revived Enlightenment is an ideal tool to promote humankind that lives in a single global community in which the challenges and problems of global socio-material systems will be met if, and only if, humans act in line with a cosmopolitan conciliation. It underscores, in declamatory terms, the universal obligation of all humans to help save the Earth and the environment, even though we have little in common with each other in regard to language, custom or culture—but we share the dependency of present and future human existence in an environment that is much less impaired in a way it is today.

[1] See also chapter Wernecke, J "Enlightenment 2.0? What we would have to change if we wanted to stay" in this volume.

Furthermore, it encourages a debate about the claim to a cosmopolitan justice for all members of the global multitude and for the environment. Drawing on Michael Hardt and Antonio Negri [49], I use the term "multitude" to describe the global public mass—the hoi polloi of the planet—as an active collective social subject acting on the basis of what individuals have in common and, thus, it is representative of an immanent, positive force.

Reviving the Enlightenment is a mental, social and political development that inspires new intellectual and public movements towards methodological cosmopolitanism. Analogously to Kant's explication of the question "What is Enlightenment?" [53], I argue that a revived Enlightenment towards cosmopolitan thinking, methodology and social being is humankind's release from its self-imposed confinement in national containers and thus from the inability to use our understanding of the Earth as a cosmopolitan community free of compartmentalized nation-states. A renewed Enlightenment is also a matter of thinking for oneself as a member of a global community rather than a national citizen and to employ and rely on its cosmopolitan capacity when tackling issues of socio-material systems and planetary common goods. It is a process of awakening and building confidence in humanity's intellectual cosmopolitan powers to ascertain knowledge and understanding about the state of the Earth system and the governing of it, which serves as a new paradigm that directs individual lives and collective social being. It unfolds a new cosmopolitan authority in contrast to traditional nation-state authority. It encourages an ontological conception of the Earth as a single entity of natural and social being highly interconnected and interdependent, and the epistemic conception of human beings as capable of knowing and understanding the singularity of these circumstances and of providing a cosmopolitan framework to address the challenges of the violated Earth through the exercise of our cosmopolitan faculties.

Like the eighteenth-century Enlightenment, a revitalized contemporary Enlightenment could give rise to tremendous intellectual and scientific progress and thereby to a transnational public rethinking of the unthinkable of an all-embracing cosmopolitan spirit. It represents the positive ideal of a universal community of world citizens where citizens still have their roots in the peculiar adherence of their countries but simultaneously form a cosmopolitan loyalty. To better understand the possibilities of a revived Enlightenment, I will begin by critically engaging with methodological nationalism, the nation-state-focused approach of mainstream social sciences and humanities (cf. [6, 8, 10, 66]). In the reading of Theodor Adorno and Max Horkheimer's dialectic ([1, 2]) as saying that the current social order is maintained because the social world has become "second nature" to us (cf. also [30]), one could argue that the social entities and categories of the nation-state and the world order governed by states are viewed as being natural. But nation-states and the intergovernmental world order are neither God-given nor natural. Rather, they are products of human covenants or conventions. Furthermore, they are no longer sufficiently adequate to meet the needs arising from global affairs and the challenges of global socio-material systems. The ideas of cosmopolitization, methodological cosmopolitanism and cosmopolitan governance and democracy progressively thwart the conception of the enduring nation-state and the intergovernmental model of the international system and thus subvert the presupposition of methodological nationalism that has guided and constrained inquiry in social sciences and humanities. A change in emphasis to methodological cosmopolitanism will stimulate social sciences and philosophy to become an independent global force with the power and authority to challenge the pigeonholed thinking characteristic of the nation-state paradigm and construct a new cosmopolitan organization of social being, both theoretically and practically.

Taking the aspiration for theoretical and practical progress and the belief that such progress will advance human society and individual lives as the core of a revived Enlightenment, this book chapter substantiates three major dimensions of methodological cosmopolitanism that are indispensable to understand and meet the global challenges our Earth is facing in the age of the Anthropocene: the rise of methodological cosmopolitanism as a new paradigm, the cosmopolitization of public understanding, and the venture towards cosmopolitan democracy. To this end, I take a stab at elucidating the desirability, feasibility and possibility of the “cosmopolitan” in our contemporary age.

2 The Rise of Methodological Cosmopolitanism

Perspectives on cosmopolitanism in philosophy and social sciences comprise both normative philosophical orientations and justifications as well as analytical-descriptive conceptualizations (cf. [10, 15, 52, 55]). They all share the view that human beings, regardless of their social and political affiliations, are all citizens of a single global community, though they conceive of this community in different ways, “some focusing on political institutions, others on moral norms or relationships, and still others focusing on shared markets or forms of cultural expression” [55]. My aim here is not to reconstruct ancient, Enlightenment or contemporary versions of cosmopolitanism. There are several dimensions of cosmopolitanism that I cannot address here; gaps will remain as to how different theorists envision cosmopolitanism. In epistemological terms, it is a question of what it is that human beings have in common and what it means for every human being to have equal moral status regardless of any particular familial, ethical, national or religious tie (cf. [6–8, 50, 52]). The purpose of this section is to outline a foundational understanding of methodological cosmopolitanism made possible by a revived Enlightenment. I elaborate on theoretical and analytical aspects of methodological cosmopolitanism that includes a systematic form of principles and procedures for inquiring about the global sphere, as well as the values and justifications that characterize cosmopolitanism. The aim of methodological cosmopolitanism is to discover new entities, methods and analytical units beyond the nation-state and their role in the international system. This is in order to generate knowledge that contextualizes the entirety of the world and that allows humans to commit to doing something on the global scale, regardless of their local and national affiliations. To this end, I refer to arguments of models of cosmopolitanism in philosophy and social sciences that help characterize methodological cosmopolitanism as a more global context-sensitive approach to theory and empiricism as well as to social and political practice.

The intergovernmental model of democratic states is viewed as a crucial model of global governance in international relations that tends towards cosmopolitanism [94, 95] because it predominates in the real-world international system and holds sway over the way in which global risks and global commons are governed. Proponents of an intergovernmental approach to cosmopolitanism contend that world politics is legitimate and favour equality to the extent that each sovereign state is internally legitimate through a functioning political system and government. Human individuals are viewed as state citizens whose interests and affectedness are represented beyond the nation-state through their national government. It is argued that the nation-states play a key normative and practical role in global governance. Some scholars argue for a more centralized world government or a federal system with a comprehensive global body and layered sovereignty based on the intergovernmental model (cf. [17, 73, 89, 90]). Although the intergovernmental model has prevailed in international relations and world politics, it is not without weaknesses. On the one hand, the majority of nation-states are not democratic so that much of the global multitude is without democratic representation at the transnational/global level. On the other hand, nation-states do not have full control over, nor necessarily significant influence on, international institutions and organizations.

State-centric and power-based theories, along with an ontology of world politics that emphasizes states as central actors and international institutions driven by states as core sites of global governance, rely on the doctrine of methodological nationalism as orientation and pattern "where social relations, networks and communities are essentially understood in a territorial sense" ([7]: 217). Methodological nationalism holds that the territorial state and its national society are unalterable, natural social and political forms and the primary entities for the analysis of political, social, economic and cultural processes [6, 8, 10, 91]. The Peace of Westphalia in 1648 marked the inception of the modern international system, establishing the nation-state, its territory and its sovereignty as the all-embracing and unconditional framework for principles of political and social powers and rights that could not be diminished in any way—a coffin for society. It entails that nation-states, or national governments, are the primary actors in world politics and global governance. The national model stands for the organization of social being, certainty and controllability, but has been undermined by a growing and accelerated globalization and an increasingly uncertain, insecure and imponderable world. Given the complex pattern of interdependence and interconnectedness of global socio-material systems and the deficiencies and ineffectiveness of existing global governance structures, there is indubitable reason to critique methodological nationalism and its sway over the international system underpinned by standard intergovernmental models.

Methodological cosmopolitanism represents a new research approach by resetting general assumptions about global entities and processes and about the appropriate methodology to be used for investigating global problems and constructing theories about the governing of these problems. It begins with the premise that nation-states and intergovernmental relations are not the centre of world politics, international relations or global governance—the totality of the Earth, including the social and natural world is. In line with Larry Laudan's [65] philosophical study on scientific change and progress, I argue that the great unmet needs brought about by global socio-material systems are not solvable by modifying specific theories within the research tradition of international relations and world politics; they are symptoms of a deeper methodological problem. By unfettering humans and their actions from the territorial confinement of nation-states, methodological cosmopolitanism heralds a paradigm change in understanding the action and manner of governing global socio-material systems. It concerns adjustments, or revisions, to the ontology, epistemology and methodology of social science research traditions, especially in terms of international relations and world politics. Thus, it entails a change in how concepts and theories are formulated and how phenomena are observed and explained.

Methodological cosmopolitanism seeks to explain social and political action in the global sphere as collective action by considering the nature of the entire world and its global multitude. Methodological cosmopolitanism claims that the world is more than the sum of nation-states; I argue that the values of the entirety of the natural and social world need to be considered and that the power of nation-states needs to be lessened and more authority accorded with collective global institutions. By arguing that human beings and the Earth system form a natural and social collective entity that is more than the sum of national territories, societies and governments, the realm of this entirety has a higher social and political status than national citizenship and affiliation. In this regard, new theoretical and analytical approaches are adapted and unfolded by which new knowledge, understanding, predictions and control in the global sphere can be generated. It reconciles the centrality of human existence in Western ethical thinking with environmental ethics, that is, new values and justifications concerning the moral relationship among all members of the global multitude and their relationship with the natural and social world as an entirety, as well as the global multitude's connection to world politics come to the fore. Drawing on the idea that all members of the global multitude have equal worth and are equally obligated, methodological cosmopolitanism seeks to ground a common global moral and ethical horizon. Methodological cosmopolitanism stipulates that endangering the global commons and violating the Earth are the result of collective acts of the global multitude, since this global collectivity alone is agentive in the wake of collectively understandable action. Methodological cosmopolitanism provides an understanding of global phenomena that commits to action-theoretical explanations at the macro-level of humanity and the Earth in its entirety. It does not involve a commitment to any particular claim about the national motives and intentions of states.

A revived Enlightenment conveys a methodological cosmopolitanism that is grounded in the foundations of cosmopolitanism as conceptualized by Kant [54] (cf. also [52, 56, 80]). Accordingly, methodological cosmopolitanism builds on two fundamental pillars. The first is that all members of the global multitude are world citizens, forming a single moral global community. Members of the global multitude are addressed as world citizens, not as state citizens. It advances to all members of the global multitude a commitment to greater objectivity and loyalty that is detached from local or national affiliations. World citizens are entitled to freedom, equality and independence. They live under a common law of morality and ethics grounded in reason. Methodological cosmopolitanism attempts to discover theoretical, analytical and practical approaches that focus on the moral commitment of members of the global multitude to justice and the democratic quality of global institutions that go beyond their commitment to their states or to relations among states. The second pillar is the public use of reason, which allows a critical vantage point to critique and remove the constraints of nation-states. In general terms, one could say that public reason in terms of cosmopolitanism must appeal to ideas and arguments that world citizens endorse and accept because they do not represent provincial and national attitudes and interests (cf. [78]). This means that members of the global multitude who internalize the idea of world citizenry must refrain from advocating national interests or supporting rules that cannot be justified to the global multitude on whom the rules would be imposed. Such members only support those norms and rules that can be justified by appealing to globally shared considerations and are not based on national interests. Public reason enables an agreement about justifiable and acceptable moral and political norms and rules that govern the social being of the global multitude and the relation to the environment.

Methodological cosmopolitanism thrives as an ontological and epistemological advancement, on a global scale, of human thinking and contextualization towards understanding and agency of a complex globalized world that stands in contradistinction to the view of methodological nationalism. Methodological cosmopolitanism controverts and debilitates the seemingly axiomatic validity and apodictic certainty of the nation-state as a bounded community, the traditional delineation of domestic from foreign politics, and the normative models of relations among states. It refutes the confidence that nation-states can still be described as "self-sufficient schemes of cooperation for all the essential purposes of human life" ([79]: 301). Self-reliance and national power are no longer sufficient or adequate when it comes to fulfilling the needs of the global socio-material system. Members of the global multitude develop a cosmopolitan attitude of world citizenry when they care about what determines who they are. The course of action that members of the global multitude as world citizens take when seeking to achieve self-determination will be accomplished and sustained by global institutions of cosmopolitan governance and democracy.

Hence, methodological cosmopolitanism introduces a methodological precept for social sciences and humanities, world politics and global governance as well as for the organization of social being in a globalized world. A theoretical, analytical and empirical global frame of reference can more satisfactorily address the global scope of research questions as well as social and political questions of global nature than can methodological nationalism [6–8, 10, 66]. It can better explain global phenomena by showing how they relate to anthropocentric actions and the behaviour of the global multitude and by elucidating that the most appropriate course of action for global socio-material systems is of a cosmopolitan nature. It involves a commitment to a global reference system and meaning structure that relinquish thinking constrained to the nation-state. It offers an alternative conceptualization of humanity and its relationship with the social and natural world as a global entirety that is not qualified by national interests. It argues that a good life for all human beings is constituted on a moral relationship between all human beings and the Earth and the rejection of a utilitarianism centred on the nation-state in favour of global ethics premised on the intrinsic value of the Earth system. World citizens forming the collectivity of the global multitude submit to the logic of reason rather than national preconceptions. In the sense of Kant's [53] public use of reason, I argue that public and practical reason can draw the members of the global multitude together to address the unmet needs regarding global socio-material systems and hence can become a conducive vehicle for cosmopolitan governance and democracy. The members of the global multitude become collective, rational agents of the Earth and its entirety when they take ethical and moral reasons and rules into account in their decisions on how to govern global socio-material systems. They share a common loyalty because they live in a single global community and share a belief in the power of reason in collective global problem solving, that is, they become a collective global entity of rational beings even as their division in the form of nation-states is fragmented into a plurality of national, compartmentalized logics and interests.

In cosmopolitan terms, we will vanquish methodological nationalism and advance towards methodological cosmopolitanism when members of the global multitude have their fair due in a cosmopolitan governing of global socio-material systems. It concerns us all that we have a common moral and ethical obligation and thus a collective responsibility to preserve the Earth and treat each other equally in the global sphere. Methodological cosmopolitanism argues that the world itself—not national or otherwise territorial compartmentalization—provides essential and valuable grounding for social, political and environmental attachment and meaning in the conception of a good life. Members of the global multitude as world citizens develop affection, fondness and sympathy for the Earth and its entirety. This attitude can break new ground and reveal special obligations to strengthen cosmopolitan governance and democracy. Notwithstanding, members of the global multitude do not forget or overlook their local communities and relationships. The community of the global multitude is closely linked to the local ones, that is, members of the global multitude see themselves as members of overlapping communities (cf. [74]). One could say that members of the global multitude develop strong attachments and allegiances to the entirety of the world in order to be able to preserve the functioning of the Earth system and a *good* organization of social being for all. This is a viability and necessity claim about humankind and the Earth and not simply a desirability claim, especially in light of the great unmet needs in the governing of global problems and challenges, such as Climate Change and the decline of biodiversity. In terms of a cosmopolitan order, methodological cosmopolitanism argues for global institutions of cosmopolitan governance and democracy that can provide all members of the global multitude with fair access to political influence. When world citizens as agents of the global multitude are involved in the design, decision-making process about or administration of global rules and norms, practices, or organizations, they feel obliged to disregard their private, local and national commitments and loyalties and impartially consider unmet planetary needs in terms of global socio-material systems (cf. [77]: 298).

In a nutshell, I am arguing that in methodological cosmopolitanism, it is morally necessary to establish global institutions of cosmopolitan governance and democracy for the functioning of the Earth system and a *good* organization of social being for all. Members of the global multitude develop a world citizenry with a commitment and loyalty that goes beyond national affiliation and mere cooperative obedience. Humans exercise relational due diligence to the Earth as a common collective that is constituted by a global obligation. It stands for an understanding and attitude that we cannot live on Earth without having a certain obligation to preserve the Earth system and create a good life for all.

3 A Cosmopolitan Perspective in the Public Understanding and Public Attitude

A revived Enlightenment towards methodological cosmopolitanism also revitalizes the genuine eighteenth-century idea of cosmopolitanism in the sense of a universal appreciation and attitude of open-mindedness and impartiality. Members of the global multitude as world citizens of a cosmopolitan community do not hold preconceived notions based on national affiliation and sovereignty or particular religious or cultural biases. World citizens strive for a cosmopolitan public understanding and attitude that arises out of scientific literacy and competence. In an Aristotelian sense, one could say that the public understanding of methodological cosmopolitanism is the application of something like practical wisdom in transnational and global public spheres and discourses that occurs as a result of practical globalization. In social science terms, public understanding and attitude with a cosmopolitan perspective on global socio-material systems is predicated on the creation of scientific literacy and competency among members of the global multitude within transnational public spheres. It means that laypersons can have insight into, show good judgment towards, perceive the intended meaning of, and favour epistemic understandings and concepts of the cosmopolitan. Scientific reasoning and justification determine the apprehension of global socio-material systems and the action and manner of governing them, a justification with reasons that can be recognized as valid. World citizens seek a rational foundation of the cosmopolitan by critically examining the justification and reasoning of perceptions and concepts. One could say that cosmopolitan literacy and sagacity appeals to those who seek a rational, cosmopoliticed foundation for the global conceptions that are used to describe global socio-material systems and their governance, and they do so by critically examining the public justification and reasoning of those concepts. In idealized terms, adequate public justification and reasoning in the spirit of a revived Enlightenment validates, by and large, the desirability, feasibility and possibility of cosmopolitan governance of global socio-material systems.

The primary aim of public understanding is to ensure that a critical reflection on the cosmopolitization of actions and manners of governing global socio-material systems is based on information, facts and objectivity. A cosmopolitan public understanding relies on critical thinking in the sense of an active and careful consideration, conveyed and facilitated by dialogue and discourse, of reliable and recognized knowledge in light of the justification of the cosmopolitan belief and the further implications of that belief (cf. [25, 26]). The concept of public understanding relies on two primary dimensions: knowledge and rationality. Knowledge in the form of facts and information acquired through scientific processes produces rationality by providing a reasonable and logical perspective but also reveals that full rationality is elusive and uncertainty remains. Knowledge and rationality are essential for public understanding because they can generate justified true, cosmopolitan beliefs. For example, humans come to understand that issues that arise out of global socio-material systems or global commons can only be tackled by collective global efforts because science clearly demonstrates they are in accordance with the present reality and established facts. So humans come to believe that only a cosmopolitan approach that includes the global multitude is a proper way to deal with global commons. For there to be public understanding about cosmopolitan thinking, humans' beliefs of the cosmopolitan must be justified, that is, it must be appropriate in an epistemic sense. Notwithstanding this, it is essential to treat a revived Enlightenment and the public understanding that is built upon it as expanding in processes and developments. Science and public understanding progress from methodological nationalism and the model of intergovernmentalism to methodological cosmopolitanism and the theory of cosmopolitan governance and democracy.

A revived Enlightenment promotes and improves public understanding of cosmopolitan thinking by reasoning and justifying the reasonableness and logic of the cosmopolitan idea. Public understanding evolves through a transnational process in which cosmopolitan literacy and sagacity are generated through the involvement of the global public multitude in transnationalized discourses of transnational public spheres. It familiarizes members of the global multitude with the cosmopolitan idea. People acquire and apply knowledge, competences and skills through actively communicating and participating in public discourses and deliberations. This idea is taken up in more detail below when I discuss cosmopolitan democracy. A cosmopolitan conceptualization of public understanding reinforces the interactive relationship between science and society. It reverses the presumption that the communication of scientific understanding flows one way—from science to society. A renewed Enlightenment makes the public understanding of and a pro-attitude towards the cosmopolitan idea thoroughly discursive and dialogic between science and society. It is a process of learning and comprehension that thrives through socialization, education and public discourses in open-minded societies. Natural, technical and social sciences as well as humanities, in particular philosophy, engage with each other and with members of the global multitude in a variety of conversational, dialogic and discursive activities directed at the exploration of arguments and reasoning in the pursuit of the "cosmopolitan vision" [6]. Dialogue and discourse are the means to contemplate and critically reflect upon the meaning of the cosmopolitan, they are the matrix for the evolution of something like a cosmopolitan public understanding. In epistemic terms, they concern the exchange of knowledge and the conveyance of justified belief aimed at answering questions such as "What are the foundation, scope and context of the cosmopolitan orientation?" "What are the conditions of the cosmopolitan?" "How plausible are cosmopolitan arguments and reasoning?" "How are we to understand the justification of the cosmopolitan?" A dialogic and discursive exploration helps us understand why the cosmopolitan turn is necessary, desirable and feasible and how it is justified. The challenge to which methodological cosmopolitanism must rise in terms of its public understanding is to give an account of what makes the approach of cosmopolitan governance and democracy better than the prevailing intergovernmental model and corresponding global governance.

Drawing on Hans-Georg Gadamer's [35] conception of understanding, I argue that the public understanding of the cosmopolitan idea is always linguistically and communicatively mediated, public understanding is grounded in the happening of communication, exchange and discourse when language forms a cosmopoliticized nexus of science and society in a world addressing contemporary global political and ethical issues. The exchange between science and society involves the interpretation of knowing and non-knowing regarding global socio-material systems and giving implied or explicit significance by translating cosmopolitan thinking and methodology into a reference system and meaning structure that is graspable for the global multitude. Thus, public understanding relies on a dialogic and discursive conception of cosmopolitan literacy, competence and empowering capacity of the public to comprehend the reasoning and justification of a shift from methodological nationalism to methodological cosmopolitanism. It becomes cosmopolitan in nature when the public is able to grasp particular cosmopolitan subject matters, based on a prior ontological understanding of the world as a whole. Public understanding is dependent on humans understanding that all human beings are in the same boat and will need to row together if we are to achieve a sustainable, effective and more democratic way of protecting and preserving the global commons.

The generation of a public understanding of methodological cosmopolitanism and issues and challenges of global socio-material systems requires a commitment to the intellectual engagement of and exchange with transnational public spheres formed by members of the global multitude as world citizens. The critical and dialectical character of a revived Enlightenment becomes evident, not merely in the central theoretical role it gives to cosmopolitan thinking and methodology, but also in the dialogical, discursive and conversational art of inquiring into ontological and epistemological contradictions and in discussing the varying beliefs, opinions and possible realities comprising the cosmopolitan vision.

Public understanding is grounded in the creation of a cosmopolitan literacy and competence in the global multitude. It provides a firm conceptual and practical basis for the cosmopolitan orientation. Cosmopolitan literacy and sagacity empowers the global multitude's ability to adopt an impartial and unprejudiced perspective and apply decisional competence. Decisional competence and empowering capacity are to be understood as the proficiency to influence political decisions in the face of uncertainty and risk (cf. [20, 22, 33, 36]). Decisional competencies and empowering capacities are intrinsic to the venture towards cosmopolitan democracy. A democratic cosmopolitan society depends on balanced and informed transnational public discourses that convey an understanding of the cosmopolitan idea in order to ensure a democratic, transnationalized formation of public opinion and political will and the application of decisional competencies and empowering capacities in cosmopolitan democratic processes. Hence, knowledge and rationality are cornerstones of a revived Enlightenment towards methodological cosmopolitanism and cosmopolitan democratization. My account of public understanding in the context of methodological cosmopolitanism suggests that all members of the global multitude can acquire a cosmopolitan understanding and thus develop decisional competence and empowering capacity if two conditions are met (1) there are scientists and experts whose knowledge, and their linguistic and communicative mediation of it, enables them to establish the plausibility of why a cosmopolitan turn is rationally necessary, morally reasonable, ethically desirable and practically feasible and (2) the members of the global multitude, who will initially be less well-informed, are capable of identifying who is a genuine and truthful expert and who is not. The empowering capacity to recognize genuine cosmopolitan knowledge and justified belief plays a significant role in the venture towards cosmopolitan democracy, though it will be challenging for members of the global multitude to trust the cosmopolitan journey into the human future. There are forces that undermine public understanding and the forming of public opinion and will and direct people away from a cosmopolitan orientation and democracy, especially in an age when concoctions of fake news, propaganda and conspiracy theories produced and communicated by political leaders, populist politicians, social influencers, social bots, or new social media manufacture specious uncertainty, risks, threats and insecurity in order to deceive the public and manipulate public discourse.

4 The Venture Towards Cosmopolitan Democracy

A revived Enlightenment and the concurrent methodological cosmopolitanism also concern the democratization of the global political sphere. There is a broad range of views and proposals about global, or cosmopolitan, democracy (e.g. [4, 5, 39, 41, 50, 64]). Many scholars reference democratic models that have been developed within the national context or build on the democratization of existing international institutions that reflect the prevailing distribution of power and the interests of nation-states, especially dominant states. Methodological cosmopolitanism provides a logical basis and a set of reasons for democratic values that can democratically justify transnational and global decision making and show that members of the global multitude are entitled to participate in the formation of global public policy is morally right and reasonable. Democracy represents the political idea that people govern themselves in their own communities, whether cities, regions or nation-states. Most models of democracy have in common the tendency to privilege inclusion, equality, self-determination and processes enabling the free forming of public opinion and political will as fundamental values and core principles (cf. [18, 21, 23, 24, 46, 51, 62, 92]). However, the idea of democracy is not inextricably wedded to nation-states and subordinated political units. The yearning for democratic self-governance in the global sphere can be satisfied if self-governance is built on the same democratic bedrock of values and principles. Cosmopolitan democracy has become associated with the aspiration of the global multitude to have the freedom to govern their common global community in and of itself rather than through intergovernmental governing. Cosmopolitan democracy opens up possibilities for members of the global multitude to shape their own lives and exercise control over global affairs by partaking in democratic processes and institutions in transnational and global spheres.

My aim here is not to reconstruct or reflect on the different approaches concerned with making world politics and global governance more democratic. This section roughly outlines a new schematic proposal for cosmopolitan democracy. My idea of cosmopolitan democracy is grounded in its functional, or instrumental, use and the intrinsic values that insist on the constructive power of reasoning and justification. Cosmopolitan democracy serves as a means to address the great unmet needs that are the result of global socio-material systems and relates to the democratic functionality of a common global entity and its essential social and democratic organization of being in the global sphere beyond nation-states. It is instrumental, or functional, in the sense that the claim of global democratic authority by means of cosmopolitan democracy is exercised through an instrumental, or functional, differentiation and division of deliberative powers that are ascribed to three essential realms of authority: epistemological, ontological and teleological, though it also substantiates intrinsic values of liberty, equality and public justification. Cosmopolitan democracy goes hand in hand with the entitlement and empowerment of all members of the global multitude to exercise their voice and political influence to debate, contest and participate in affairs of global socio-material systems. The exertion of the authority of cosmopolitan democracy relies on deliberative processes that expand the classic ideals of deliberative democracy, that is, participants strive to form a reasoned convergence and consensus but also accept and tolerate forms of incomplete agreement, negotiated compromise or agreed upon dissent as possible outcomes when viewpoints, beliefs and values do not conflate and remain ambiguous (cf. [68, 75]). I argue that the essential factor that makes cosmopolitan democracy possible, analogous to the idea of public reason (see [14, 19, 27, 28, 47, 48, 76, 78]), is that the interplay of epistemological, ontological and teleological authority has the ability to produce global public policies that can be recognized as democratically legitimate in that they bring about decisions in which public reasoning and justification grounded on rationality and morality have been used. Members of the global multitude engage as world citizens in discourse and deliberation with others and commit themselves to the idea of public reason as the give and take of rational arguments and moral norms. They commit themselves to develop global public policies that can be commonly accepted by all members of the global multitude without coercion because they meet the unmet needs arising from the governing of global socio-material systems. Accordingly, the constituents, or building blocks, of my proposal of cosmopolitan democracy are three kinds of democratic authority conveyed by rational discourse and public deliberation: epistemological, ontological and teleological authority.[2]

5 Epistemological Authority

Epistemological authority represents an institution of cosmopolitan democracy that is responsible for the acquisition of truth by aggregating theoretical, empirical and practical knowledge and understanding of global subjects and phenomena. It yields the expertise necessary to properly govern the challenges and issues arising from global socio-material systems. Drawing on the philosophical theory of social epistemology [37], I argue that epistemological authority is a collective undertaking where collections of individual epistemic agents or collective epistemic agents try to determine what is true, what the facts of the matter are, what is uncertain, how complexity can be addressed, etc. We conceive of epistemological authority as being positioned within a global context. Accordingly, using epistemological authority is thought to be the best democratic method on the grounds to acquire knowledge and understanding that is epistemically most reliable in helping members of the global multitude as world citizens discover the right decisions. Epistemological authority is thus concerned with the following questions: What is the necessary and sufficient body of knowledge for decision making about global risks and the global commons? What are the limits of this knowledge and how is it constrained through epistemological uncertainty? How can scholars and experts aggregate their beliefs? How are members of the global multitude as world citizens to understand and interpret the acquired knowledge? In answering these questions, methodological cosmopolitanism is used as the methodology to create meaning that is essential to understanding and interpreting issues and challenges of global socio-material systems. Evidence-based statements, reliable scientific studies and the most recent specialized state of knowledge are important to this end. However, knowing facts, information or precise details about global phenomena without a corresponding understanding and subsumption can hardly serve as a useful epistemic bedrock for addressing the challenges of global socio-material systems in a democratic frame of governance. Democratic processes of public opinion and political will formation by the global multitude need to be predicated on valid and trustworthy assessments and judgments. Laypersons trust experts whose opinions are plausible and reasonable. Expert advisory bodies, institutes of higher education, independent research institutes, non-profit organizations, impartial think tanks, and independent state-run research agencies provide the relevant issue-specific expertise, competence and necessary understandings. Research units possess substantial authority because they operate with a sense of credible obligation when it comes to the objective and unprejudiced production of expert knowledge and

[2] In a recent book chapter on cosmopolitan governance for sustainable global energy transformation, I also conceptualize three major democratic-deliberative authorities that take a similar direction, see Klinke [62]. See also [61].

systematic information that is generally accepted in the public sphere. By connecting and collaborating in epistemic communities and global institutions, they are able to collectively facilitate agreement on cognitive and normative ideas about global public policy-relevant problem solving (cf. [43–45]). Hence, epistemic communities and their global institutions, with a multiplicity of working groups, goals, as well as coordination and aggregation mechanisms to attain collective output, possess the necessary epistemological authority as a scientific entity. Since truth-seeking motivates scientific experts, communication and deliberation within the authoritative epistemological community aim at cognitive convergence. One could say that epistemic agents are morally committed to objective norms of rationality. Their overall goal is to establish a rationally reasoned consensus about cause-and-effect relationships, uncertainties and ambiguities, and policy-relevant criteria for judging societal acceptability and tolerability.

In doing so, the epistemological authority also makes it known that criteria for judging acceptability and tolerability might be burdened with social, cultural and historical presuppositions and contexts. Therefore, it is necessary to distinguish and clarify causal and principled beliefs and worldviews [38]. These foundations help the global multitude understand underlying frames of reference and meaning structures. Causal beliefs provide evidence of causal inferences, for example, that there is a connection between a renewable energy supply and a decrease of carbon emissions. Principled beliefs are expressed in ideational norms and rules that help us distinguish between right and wrong and just and unjust when, for example, evaluating how much fossil energy is acceptable to use when the goal is to meet Climate Change reduction targets and what is a reasonable distribution of renewable and fossil energy in a transition period to a sustainable society. It is also important to make the public aware of conflicts and moral disagreements that arise when traditional perspectives are at odds with progressive and innovative action. Additionally, we learn that principled beliefs, even conflicting ones, are embedded in larger belief systems or worldviews. Worldviews in this regard are based on value systems that include views about the economic and social organization of human existence. The beliefs that makeup worldviews are not detached from each other but, rather, are interdependent: "Causal beliefs imply strategies for the attainment of goals, themselves valued because of shared principled beliefs, and understandable only within the context of broader world views" ([38]: 10).

The worldwide network of climate researchers and its institutional focal point, the Intergovernmental Panel on Climate Change (IPCC), as well as its regular assessment and evaluation reports can be viewed as an approximation of epistemological authority within cosmopolitan democracy. The problem is that the functioning of the IPCC and the approval of its reports follow the intergovernmental model. In other words, nation-states have a final say on the content of the reports.

6 Ontological Authority

Ontological authority is predicated on associational deliberations among transnational social groups that are viewed as collective agents of a world citizenry. Transnational social groups are realizations of structures that are made up of nodes, relations and operations across national borders.[3] It draws on the idea of associational democracy—that social groups can carry out central democratic functions (cf. [29, 88])—and also on descriptive representation as a medium of democratic representation, that is, an array of transnational groups represent the social diversity, plurality of views and underlying beliefs and values of the global multitude (cf. [75]: 154–155). It is a new form of political representation in the global sphere and is not characterized by the formal relationship between elected representatives and their constituents within nation-states or intergovernmental arrangements in the international system. Important global ontological responsibilities are no longer assigned to nation-states and their representation in the international system; they are functionally ascribed to an authority formed by transnational social groups, that is, nation-states' ontological powers are devolved to non-territorial, non-state actors that represent the global common good, and not national interests. Transnational social groups act as ontological representatives of the members of the global multitude by making known their perspectives on and opinions of the ontological challenges and issues to be considered in cosmopolitan democracy. In this capacity, they are trusted by the global multitude because they resemble in their descriptive characteristics and substantive cosmopolitan attitudes of the global multitude they represent.

For transnational groups to participate in associational deliberations that carry ontological authority, they must adhere to cosmopolitan beliefs, attitudes, intentions and attention to the entirety of the Earth and hold to non-profit, collective norms and values that are oriented to the common good. They must respect the global multitude's experiential knowledge and practical wisdom when it comes to generalizable global ethical, societal and political implications. Members of these groups must have cosmopolitan attitudes and mindsets and participate knowledgeably in coordination with each other to achieve cosmopolitan goals. Thus, the collective identity of these groups is composed of the aggregation of the members' cosmopolitan attitudes, rather than their national thinking and affection. Collective, intentional, cosmopolitan attitudes permeate national identities. In line with theories of collective intentionality [83], I argue that world citizens with open and transnational mindsets and mental states can establish a basic common ground that allows transnational groups to cooperate with each other within associational deliberations in their search for collective acceptance in the face of ontological challenges and issues. By virtue of a cosmopolitan allegiance and solid support for each other, transnational groups

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[3] The understanding of transnational groups refers to the philosophical account of social groups. See Ritchie [79] and Epstein [28].

can reason from the perspective of the common good and conceive of themselves, in terms of their social identities and social roles, as collective agents of a world citizenry.

Transnational groups establish ontological authority when they engage in associational deliberation that entails prudent consideration and discussions of the ontological dimensions and implications of the challenges and issues arising from global socio-material systems. The epistemic frames of reference and meaning structures produced by the epistemological authority provide a common cognitive and evaluative stock of knowledge and understanding about causal and principled beliefs, including conceptions of the global common good and global commons, against which ontological questions and challenges are deliberated. Essentially, these associational deliberations concern the contextualization of challenges and issues that refer to human existence, the global community as a whole, the consequences of human behaviour, action and lifestyles, modernization and the organization of social being which are enmeshed in global socio-material systems. In doing so, they provide an ontological framework for understanding and interpretation as well as ascertaining moral and ethical acceptability and tolerability in the global sphere. To ensure a proper ontological understanding and framework as well as a democratic-deliberative generation of the accord, collective agents in associational deliberation accept considerations that are justified and persuasive, even if they disagree with them, that is, they focus on mutual reasoned justification. Ontological authority comes with problems as it is not clear how to approach and settle questions of appropriateness and inclusion of issues. Hence, associational deliberation also needs to include debate and justification of what is appropriate with regard to ontological content and who is entitled to settle these questions. Ontological authority brings with it a rational and moral commitment to answer these relevant questions; collective agents share the democratic belief and obligation that they are responsible and accountable for a certain course or principles of action proposed or adopted in respect of essential parts of social being and procedural aspects of cosmopolitan democracy. This responsibility and accountability also brings with it a commitment to non-responses and dissent regarding ontological inferences.

The collective responsibility of transnational groups to deliberate and resolve ontological challenges means that ontological authority represents a global ethical and moral force. It is capable of providing an ontological corridor for a kind of cosmopolitan narrative, a realm of cosmopolitan principled beliefs and worldviews that includes foregone conclusions and overarching aims and values that frame specific courses of action, modified behaviour patterns, adjusted lifestyles, cosmopoliticized modernization, global moral commitments, and the organization of social being on the global scale, in order to meet the great unmet needs arising from socio-material systems. This means that in methodological cosmopolitanism, moral agency is associated with transnational groups in which the members of the global multitude ascribe collective moral responsibility to collective agents in the global sphere in a fair manner. I argue that, analogous to the philosophical focus of forward-looking collective responsibility [34], [69: Chap. 7], [70, 71, 93], ontological authority is essential for engendering and mediating a desirable ontological account of the modes of human existence and the organization of social being in the context of global socio-material systems, which, in turn, the global multitude can consider and accept as being right, good and sustainable for the common good of all. By virtue of the ascribed collective global responsibility, inducing moral acceptability and tolerability becomes a part of the moral concern engendered by ontological authority. Associational deliberations, when drawing on ontological authority, are entrusted with a global moral task. The members of the global multitude allow the ontological authority to represent the peoples' public judgment and conclusions concerning ontological challenges and issues, but, likewise, the global multitude also expects that transnational groups will exercise their common judgment wisely in a cosmopolitan spirit and come to globally sensible conclusions. The forward-looking collective responsibility engendered by ontological authority is morally salient if global moral responsibility is taken seriously by transnational groups and if they bring about a better cosmopolitan relationship between the social and natural world and a respective organization of social being (cf. [69]: Chap. 7).

7 Teleological Authority

Due to the great unmet needs arising from global socio-material systems, members of the global multitude as world citizens engage in communication about common concerns extending across national boundaries, which brings trans/international public spheres into being. World citizens impart and exchange information, facts, understandings and opinions, they share ideas and affection, and they stimulate discussion and debate. The exchange and discourse relate to common contextual frames of reference in relation to observation, perception, action and interdependence. These trans/international public spheres thrive through the trans/internationalization of discourse and dialogue that give rise to the unfolding of a new, cosmopolitan "space for the communicative generation of public opinion" ([32]: 7) acting as mediating authority between the global multitude and democratic global public policy making.[4] Commenting on, asserting that, being of the opinion that, believing in, objecting, contradicting, and reacting to what other speakers say in a trans/international context shapes discursive arenas for a communicative formation of public opinion and will. Transnational public spheres forming public opinion and political will have the potential to become entities of the democratic, cosmopolitan agency.

The engagement of members of the global multitude in trans/internationalized arenas of public formation of opinion and will lead to the establishment of a

[4] For a discussion on the role and function of transnational public sphere, see also Risse [78] and Steffek [82].

trans/internationalized public community of continuing discourse and dialogue. If such transnational communities conceive of collective efforts and cosmopolitan intentions as the best means for formulating global public policies, then the keystone for the creation and institutionalization of teleological authority as a central pillar of cosmopolitan democracy has been identified. Thus, the trans/internationalization of public communication and discourse among the global multitude segues into a cosmopolitan public community—a cosmopoliticized democratic demos of world citizens across national boundaries and hierarchies without predestined jurisdictions (cf. [59, 60, 61]). What does that mean?

It means that the teleological authority of cosmopolitan democracy is generated by public deliberation of the global multitude. Individuals of the global multitude are entitled to carefully consider, debate and formulate global public policies arising from means-end reasoning and justification. It is a global democratic authority with a teleological orientation in that members of the global multitude as world citizens have the cosmopolitan competence and are morally committed to rationally reason and justify forward-looking goals and purposes and identify the means of achieving them. It becomes effective when the trans/international discourses and the forming of global public opinion and will are channelled and aggregated through forms and procedures of public deliberation that fulfil an "*equal opportunity of access to political influence*" ([63]: 280, italics in original) for members of the global multitude. Public deliberation can be organized as mini-publics in the form of consensus conferences, citizen juries or panels, or deliberative opinion polls [31, 40, 42, 57, 58, 67, 72]. Global mini-publics in which participants are selected by sortation warrant the substantial participation of members of the global multitude in a process of reasoned deliberation among equals. It is the democratic purpose of public deliberation to formulate global public policies, through reciprocating and exchanging views and arguments, that morally commits the participants to rationally reason and justify how the selected policies serve to address challenges and issues arising from global socio-material systems.

To acquire teleological authority, public deliberations by means of mini-publics draw on epistemic frames of reference frames and meaning structures as well as the given ontological corridor and narrative. Participating members of the global multitude hear the evidence and learn of the reasons that underlie the issues and challenges of global socio-material systems from scientific experts of the epistemological authority and then question them. They should also be presented with the perspective and understanding produced by the ontological authority and hear testimony from collective transnational agents about the ontological reasons that justify moral and ethical acceptability and tolerability. In this way, participating members of the global multitude attain sufficient knowledge and understanding as well as ontological sagacity and reflection to deliberate teleologically. The non-coercive nature of public deliberation motivates the participants to attain instrumental rationality, that is, they formulate global public policies and engage the means necessary to achieve the desired end. It presupposes that there are objective epistemic reasons and ontological values that are independent of national, partisan or subjective interests and that provide cosmopolitan standards for assessing possible outcomes. Instrumental rationality represents in some sense a teleological and normative function of public deliberation. The participants are rationally and morally prompted to select the means that are required to achieve the desired end, through the public use of reason.

8 Conclusion

Methodological cosmopolitanism has been embroiled in highly politicized debates in recent years, largely because it is often invoked as a counterpart of communitarianism and populism or as a way of discrediting the nation-state. It is not a political or ideological doctrine that holds a set of beliefs. It would also be a serious misunderstanding to think that it involves what is in any conceivable sense a universal system of values. I view methodological cosmopolitanism as a theoretical, methodological and analytical thinkingness that accentuates and foregrounds a universal, unnational, non-provincial and non-sectarian quality of thinking about the Earth as an entirety. A revived Enlightenment seeks to bring about a methodological realignment of the planetary state, new methodological conditions for social sciences and social and political reality and practice by broadening the model of action in such a way as to bring to the fore an action-theoretical understanding of the Earth, on a macro-scale. Social sciences that include interpretation as part of their explanations and real-world global governance that aims at the global capacity to act, both have a methodological reason for privileging a cosmopolitan view that incorporates the collectivity of the global multitude, since it is precisely the entirety of all human beings and the Earth system that serve as their subject matter.

To borrow the classical Enlightenment metaphor, methodological cosmopolitanism attempts to bring light into the darkness brought about by methodological nationalism and a normative world order under the sway of nation-states. It is a new intellectual orientation, a new perceptual structure and social scientific and philosophical approach that conceives of the entire Earth and its collectivity of the global multitude as a social and political entity and thus as a central analytical unit. It moves away from the compartmentalization of nation-states and the idea that nation-states are natural containers of social processes and seeks to leave behind the heritage of methodological nationalism when it comes to the governing of global socio-material systems. It provides a new metaphysical framework within which to place and interpret knowledge in relation to the Earth as a whole, to understand the planetary conditions, to understand human understanding in a cosmopolitan context, to understand pertaining cognitive successes and failures, as well as to situate and interpret a global morality and ethics.

Accounting for a novel system of theoretical reflection, empirical analysis and theory development, methodological cosmopolitanism no longer relies on the self-explanatory nation-state container as the ontological and epistemological entity of political, social and environmental affiliation and ties. The global multitude as a collective social subject is nested in de-territorialized networks of social, political and environmental relations and interdependences whose scope discards national fetters and over which individual members of the multitude have no or very limited control.

A revived Enlightenment towards methodological cosmopolitanism heralds a new cosmopolitan epoch in which human spirit and endeavour takes a stab at dealing with the uncertainty of post- or second modernity and that brings into being a new organization of global social being, a new kind of economy beyond classical capitalism, and a new, more democratic global order. It inspires and illuminates the democratic (re)organization of the political order and social being on the global scale, in accord with a critique of existing global governance institutions and the theoretical construction of democratic, cosmopolitan institutions as they ought to be. It acknowledges that the ideas of all members of the global multitude are world citizens and form a world citizenry from a moral point of view. It recognizes the importance of transnational and global public spheres and a functional, or instrumental, division of democratic labour that defines the role for world citizens in a cosmopolitan democracy.

Methodological cosmopolitanism assumes that members of the global multitude stand in a social and political relationship with each other and that their collective connectedness and interdependence prompt them to create and maintain a collective ground of self-governing to serve common interests and benefits and collective well-being. It constitutes the common good of the global multitude and serves as a shared bedrock for public and practical reasoning. Analogous to the philosophical accounts of public and practical reason [78, 87], I argue that public and practical reasoning, within the framework of methodological cosmopolitanism, is the public exertion of the general human faculty to resolve, through reflection and deliberative self-determination, the question of what the global multitude can do to engage in sustainable action and govern global socio-material systems. The purpose of collective public and practical reasoning is to find solutions that are feasible and effective in real circumstances and commit members of the multitude to act accordingly. In this regard, cosmopolitan democracy gains democratic legitimacy when the members of the global multitude recognize that the new functionally differentiated cosmopolitan authorities can make competent, fair and morally acceptable judgments and binding decisions, and conceive of their epistemic reference frames and meaning structures, ontological narratives and principles, and the norms, rules and procedures of global public policies as the best means possible to address the issues and challenges arising from global socio-material systems.

A new Enlightenment inspires societies and their citizens to shatter and leave their cocoons of nation-states, which envelop them in a comfortable and protective way, and their intergovernmental organizations, which form the basic blueprint of practically all action and pattern of governing global commons, to metamorphosize into a cosmopolitan democratic citizenry. The domestic arena is no longer a privileged site for governing socio-material systems and the realization of democracy. If we take principles of justice and democracy seriously, it is no longer self-evident that nation-states and intergovernmentalism are the appropriate vehicles for coping with global phenomena since global socio-material systems are deeply and irrevocably intermeshed networks across the domestic-foreign divide that permeate the natural and social world. We must advance towards methodological cosmopolitanism in order to protect the entirety of the Earth by forming a cosmopolitan loyalty and transforming ourselves into a democratic cosmopolitan citizenry. The venture towards cosmopolitan democracy is a risky and daring human journey, but it is the only advancement in the process of civilization and modernization that is in the spirit of Enlightenment and expedient for the entirety of the Earth.

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A Different Look at Consumption: From Quantitative to Sustainable Consumption

Michael von Hauff and Monika Schappert

Abstract There is a broad consensus that consumption is a major driver of growth, yet the demand side is rarely adequately considered in explanations of growth. Instead, the focus tends to lie on the relationship between growth and economic development. Growth theory states that economic growth is based on production factors such as technological advances and human capital. Accordingly, growth is primarily explained in terms of production (supply side). What gives such great significance to growth is the information provided by it about the economic performance or the dynamics of an economy. It also indicates the level of prosperity (per capita income) in society. Growth contributes to the stability of labor markets, social security systems, and the financial strength of government budgets. Therefore, growth enjoys a high priority in economics as well as in politics.

Keywords Consumption · Sustainable consumption · Growth · Consumers' sovereignty · Sustainable development goals

1 Introduction

There is a broad consensus that consumption is a major driver of growth, yet the demand side is rarely adequately considered in explanations of growth. Instead, the focus tends to lie on the relationship between growth and economic development. Growth theory states that economic growth is based on production factors such as technological advances and human capital. Accordingly, growth is primarily explained in terms of production (supply side). What gives such great significance to growth is the information provided by it about the economic performance or the dynamics of an economy. It also indicates the level of prosperity (per capita income) in

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society. Growth contributes to the stability of labor markets, social security systems, and the financial strength of government budgets. Therefore, growth enjoys a high priority in economics as well as in politics.

The positive economic growth in Germany in 2016 and the two following years was largely attributed to consumption. In light of this, there is good reason to focus on consumption as an important, if not the key driver of actual dynamic growth (OECD, 2016). According to mainstream economists, this new emphasis is seen as positive and desirable. Nowadays, economic growth or dynamic growth is increasingly being studied in terms of consumption, i.e., the demand side. In this view, the basic determinants are income development and private household savings. These factors are determined mainly by the development of the labor market: rising employment increases the national income, which generally leads to greater consumer demand.

However, just like production side growth, consumer-driven growth also is increasingly criticized for its negative effects, especially on the environment. Even more scrutiny is further being given to the societal impacts of increasing consumption. This has given rise to terms like "the consumer society" in which the maxim is to satisfy as many needs as possible through consumption [12, 36].

In the paradigm of sustainable development, such consumers' sovereignty is at odds with sustainable consumption. It is useful to address the two concepts of consumers' sovereignty and sustainable consumption separately. On this basis, the differences can be deduced and the effects of each on consumption-driven growth can be exemplified. Although the call for sustainable consumption is growing louder, the prevailing consumerism—until now the dominant pattern of consumption among the broad population—may be described as clearly unsustainable and, consequently, as having a negative effect on sustainable development [21]. The following discussion addresses the barriers preventing the spread of sustainable consumption and, ultimately, reaches conclusions about what can and must be done to promote sustainable consumption.

2 The Paradigm of Consumers' Sovereignty

The idea of consumers' sovereignty can be traced back to the father of modern economics, Adam Smith. In his major work, published in 1776, he suggested the primacy of consumer interests: "Consumption is the sole end and purpose of all production; and the interests of the producer ought to be attended only so far as it may be necessary for promoting the consumer interests" [34]. The term itself, "consumers' sovereignty," was introduced much later by English economist Hutt in a publication from 1936: "The consumer is sovereign when, in his role of citizen, he does not delegate to political institutions for authoritarian use the power which he can exercise socially through his power to demand (or refrain from demanding)" ([18]: 257). For him, there are normative reasons for consumers' sovereignty, founded on the principles of liberty and justice. Hutt assumed that individuals do not always fully understand their own interests. Since politicians are in even less of a position to know the interests of individuals, he considers any state influence as problematic.

In modern economics, the starting point for consumers' sovereignty from a microeconomic perspective is that every consumer carries out his plans within the consumption opportunities provided. From a micro-economic perspective, there is also a rigid correspondence between choice, preference, and welfare ([32]: 67). This effectively is a reinterpretation of an originally nomocratic (rule or process-oriented) concept of consumers' sovereignty into a teleological (goal-driven) concept. Hence, there is a confusion of the nomocratic explanation (which aims at the freedom of choice) with the teleological explanation (which aims at material well-being). In this context, microeconomists additionally assume that human needs are fundamentally infinite, which is largely owed to utility function calculus (Korn, 2014: 255). In principle, logically there are no limits to the satisfaction of needs. Looking at this from the producers' perspective, the continued development and redesign of goods and services is justified by the infinity of human needs.

The freedom of choice and self-determination provided by consumers' sovereignty are regarded as the highest good. As explained by Sturn: "The real interests of real people should determine what is preferable for the good life, not the ideas of some ideologues or utopians" (2013: 16). Consumers' sovereignty can still provide a relatively high degree of individual freedom of choice even in widely regulated economies. Consumers have a large interest in preserving this freedom. According to a model suggested by Becker, changes in the budgetary and production functions occur within the framework of an endogenous shift in preferences. However, the utility function remains constant [3]. A shift in preferences does not alter the utility function.

Analogous to Adam Smith, the assumption today is that consumers have no coherent or consistent preference system. Consequently, at least some individuals do not know their true preferences, which may vary, seemingly irrationally. Preferences can change in the long term, which means they are not stable. Lerch believes this not to be in disfavor of consumers' sovereignty. However, he suggests a differentiation is required between individual consumer choices that affect only the individual and those consumer decisions that also affect the community (for example, in terms of environmental pollution). When consumption is associated with an environmental burden that affects the common welfare, restrictions to consumers' sovereignty are justified. The problem was already recognized by Hutt. He differentiates between consumers' sovereignty and electors' sovereignty: "Real controversies, it seems, must center round the problem which is actually "collective" in nature" ([19]: 66, FN 3).

Insofar as individual consumption causes collective suffering, consumers' sovereignty can therefore very much be restricted or abolished, if need be, by the state. This has long been common for goods like prescription drugs, narcotics, or firearms, which can cause public health damage or endanger public safety. In the EU common market it has further for decades been obligatory that all goods imported and produced carry a CE marking and therefore declaredly comply with standards for health, safety, and environmental protection. This ranges from the safety of toys through construction products to pyrotechnics. Chemicals are, for example, subject to the EU's strict REACH regulation. These regulations in fact both assist consumers and protect society by largely preventing harmful products from even coming on the market. Biocides are another example of regulated consumption—despite being popular in private gardens, as an anti-bacterial cleaning agent in homes, or as insect repellent aerosol (Regulation EU 528/2012). As the biocide example shows, consumers may still be able to obtain harmful products but must use them cautiously and parsimoniously. However, consumers generally have the option to avoid environmental (and societal) damage and its cost by complying with environmental regulatory standards.

Ultimately, Lerch concludes: "The operative effect of individual preferences must be limited everywhere that the rights of others (even in the future) are impacted" ([23]: 184). This position is already firmly ingrained in the sustainable development paradigm and principle of intergenerational equity. A contemporary example of this is the pricing of CO_2 emissions: producers and consumers must either pay a price when they cause CO_2 emissions or get relief when they choose to consume relatively little CO_2 (for example, the decision to use fuel-efficient cars, energy-saving heating systems, or renewable energies).

People find themselves in the middle of a growing dilemma: On the one hand, they have a right to freedom of choice and self-determination, while on the other hand, limits to consumers' sovereignty must be respected for the protection of all people. This can be observed in the inconsistent behavior of many people: "People tend to focus too much on the status quo; they are too comfortable, confused, or weak-willed and may follow all sorts of impulses. The arithmetic skills of most are severely limited anyway" ([35]: 16). This observation presents two contrasting issues: 1) When is it legitimate for the state to interfere with consumers' sovereignty, which may lead to restrictions on individual rights? Or, under what conditions do the restrictions imposed on consumers' sovereignty lead to an improvement in the quality of life with greater individual abilities or freedoms [31]?

Consumption is generally discussed in terms of macroeconomic consumption, where rising consumption is often associated per se with pollution and therefore, as undesirable. In this context, some differentiation is required to show which consumer products and services actually do contribute to the ecological and/or social burden. An increase in the consumption of some other goods and services is judged as having a positive impact. Such goods include, for example, education and health care services as well as organic products and renewable energies that have a relatively low impact on the environment and are therefore socially and politically desirable. These, in fact, are contributing to sustainable growth.

3 Prerequisites for Sustainable Consumption

The term sustainable consumption originated with the discussions of sustainable development. Specifying the definition of sustainable development in the Brundtland Report, Balderjahn defines sustainable consumption as follows: "Sustainable consumption means acting to satisfy [one's] own needs without jeopardizing the quality of life and consumption opportunities of others (the principle of intragenerational justice) or of future generations (the principle of intergenerational fairness)" ([1]: 202).

Sustainable consumption was originally anchored in Agenda 21, the action plan adopted at the Earth Summit Conference held in Rio in 1992: "To date, the growing knowledge about the importance of confronting consumption has not been adequately met with a corresponding understanding of the impacts. Some economists now question the traditional economic growth concept and highlight the need to pursue economic objectives that take the full value of net capital into account. Establishing coherent international and national policies requires a more detailed understanding of the role that consumption plays in economic growth and population dynamics" ([6]: 18).

Under the heading "Changing consumer habits," a movement was started to deal with unsustainable consumption patterns and demand the development of national policies regarding the change. In practice, the development of sustainable consumption or sustainable consumer behavior turns out to be a relatively complex undertaking. To ascertain sustainable consumer behavior, it is useful to differentiate individual consumer actions. It is possible to evaluate the reasons behind a person's intent to consume and the effects that result from that behavior. Not only the intention but also the effect must meet the standards of sustainable development. Consumer actions may be based on a sustainable intention, yet that does not necessarily lead to a sustainable effect and vice versa ([11]: 19).

For example, empirical studies have shown that the upper class and upper-middle class demonstrate above-average environmental awareness, and yet, at the same time, they consume the most resources [22]. It is not sufficient to consume ecologically friendly products while neglecting those measures with a high environmental impact [5]. On the other hand, some consumer actions may not have any long-term intention but still result in a sustainable effect. Consumers, for example, who visit the weekly farmer's market for personal pleasure instead of going to the supermarket or prefer the comfort of a regional vacation over some distant vacation destination, have no intention of acting for reasons of sustainability. The effects of such consumer behavior are nevertheless positive in terms of sustainability. Consumer actions may be called sustainable only in relation to both intention and effect.

The effect of consumer actions on sustainability can be measured in terms of resource consumption (wells) and/or emissions (sinks) ([4]: 144). One currently popular possibility is to relate consumer actions to their CO_2 emissions (see Fig. 1). Vice versa, raw material, land, water, and energy consumption are also to be taken into account and can paint a somewhat different picture. For example, the CO_2 emissions

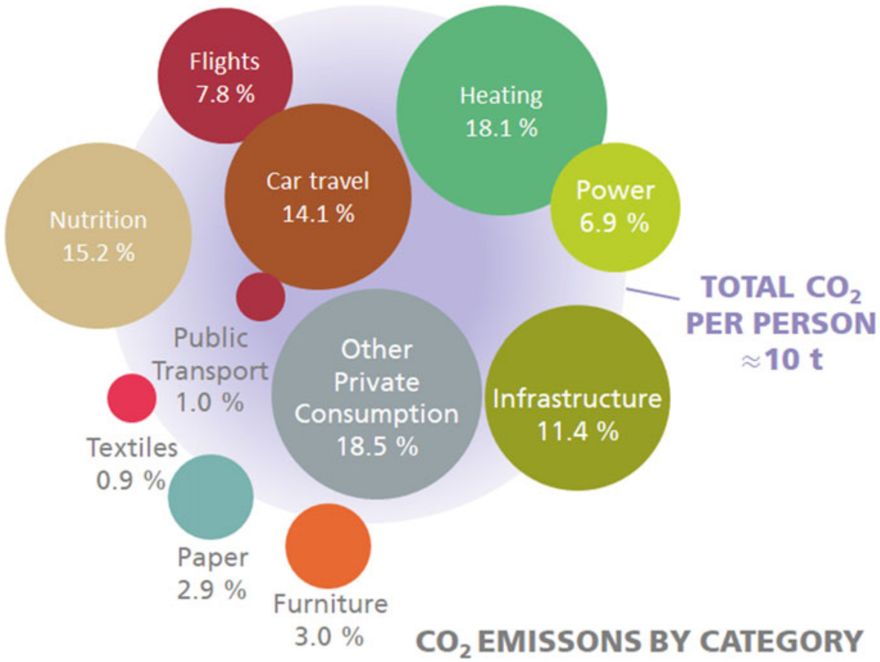

Fig. 1 CO_2 emissions by category. Graphic adapted from RNE: Der nachhaltige Warenkorb (The sustainable shopping cart). Berlin: Rat für nachhaltige Entwicklung, 2017; based on data by Grießhammer et al. [14]

of textile (clothing) consumption are relatively low, whereas water consumption and pollution are very high [27]. Even this view does not include the social dimension of sustainability, which encompasses the health and rights of workers in the clothing industry.

Many opportunities exist today to practice sustainable consumption. The following areas, in particular, lend themselves to this purpose (details in Fischer and von Hauff [11]: 38ff):

- Mobility (e.g., car travel and flights),
- Nutrition,
- Clothing and electronics,
- Disposal of prosperity ballast (decluttering).
- Housing (space heating/cooling and power consumption).

When all international agreements are considered, Agenda 2030 with its 17 Sustainable Development Goals (SDGs) is especially significant. All charter members of the United Nations have recognized the agreement and have committed to developing national implementation strategies. The SDGs target global development, which encourages all countries to cooperate for their own mutual benefit. Achieving progress toward sustainable development is one exigency, especially, in the Global

South. Goals have been defined with this factor in mind. The goals are interdependent, fundamentally linked together, globally oriented, and universally applicable while taking into account the different realities found in the individual countries. They range from poverty (1), hunger (2), health (3), education (4), women's empowerment (5), water (6), energy (7), growth (8), infrastructure (9), inequality (10), cities (11) through sustainable consumption and production (12) to climate change (13), oceans (14), biodiversity (15), peace (16), and partnerships (17).

The goals and their targets are an expression of a global effort. How these are put into practice and implemented is up to the various national governments. In the context of sustainable consumption, SDG 12 is the most important. It basically states that only a change in consumer habits and a transition to environmentally sound production methods will ensure the achievement of a new economy and a way of life that respects the natural limits of the Earth.

Agenda 2030 calls for sustainable consumption and production through the implementation of a 10-year framework program (10YFP) of sustainable management and use of natural resources, as well as a 50% reduction in food waste per capita. By 2020, a more environmentally friendly way of dealing with chemicals and waste is to be achieved that significantly reduces their production and release into the environment ([16]: 44). SDG 12 comprises 11 targets. The following SDG 12 targets are applicable to sustainable consumption:

Goal 12. Ensure responsible consumption and production

12.1 Implement the **10-year framework program** on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries.

12.2 By 2030, achieve the sustainable management and efficient use of **natural resources.**

12.3 By 2030, halve per capita global **food waste** at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.

12.5 By 2030, substantially **reduce waste** generation through prevention, reduction, recycling, and reuse.

12.8 By 2030, ensure that people everywhere have the relevant **information** and awareness of sustainable development and lifestyles in harmony with nature.

The remaining targets 12.4 (chemicals), 12.6 (corporate reporting), and 12.7 (public procurement) as well as 12.A (development countries), 12.B (tourism), and 12.C (subsidies) refer to companies or governments and do not directly address consumers; therefore, they are not reproduced in detail here.

4 Obstacles to Implementing Sustainable Consumption

The previous section clearly shows that sustainable consumption is becoming a significant challenge to sustainable development. This statement is based on the growing number of studies that find rising consumption tends to produce more environmental pollution. In other words, increasing consumption is associated with environmentally damaging growth. This applies both to the high and rising consumption-related emissions as well as to the growing use of raw materials, for example, rare earth elements and metals.

One major obstacle to a sharper focus on sustainable consumption stems from the deeply rooted desire for freedom of choice that influences consumers' sovereignty. The rising income levels in many countries that lead to a greater awareness of an ever-greater range of available choices, in effect, contribute to increased consumption. Also, there is a path dependency to consumption patterns, which can be illustrated using the example of plastic waste. The negative consequences of plastic trash, especially in our oceans, are widely known: "Projected growth in plastics production in a business-as usual scenario could lead, by 2050, to the oceans containing more plastic than fish (in weight)" ([10]: 22).

The actions taken to significantly reduce this major problem have been relatively few. Overall packaging waste (glass, paper, metal, and plastic) has increased in Germany 7–13 times since 2000 [37]. Many other problem areas from consumption-related environmental damage also exist with little action to combat them; namely, the dramatic loss of biodiversity, the accelerating climate change, and the growing worldwide water shortage. As early as the eighteenth century, Alexander von Humboldt observed that "By felling the trees which cover the tops and sides of mountains, men in all climates seem to bring upon future generations two calamities at once; want of fuel and a scarcity of water" ([17]: 9). Major environmental damage is caused by consumption in the areas of construction and housing, including space heating, electrical power, mobility, and food production. The prevailing production systems and Western-style consumption are cited, in particular, as leading drivers of global environmental pollution [9, 41].

The negative ecological consequences of consumption are fairly clear, but the harmful social impacts from the rising levels of consumption are not as well-known. The widespread economic view that increasing consumption leads to increased individual and overall social well-being has been critically questioned from the beginning. In the seventeenth century, the great English philosopher Thomas Hobbes first suggested that the pervasive worries and fears of society are characterized by unlimited materialistic values. John Galbraith's book "The Affluent Society," published in the 1950s, identified the primarily negative ecological and social consequences for a consumer society.

Throughout the following decades, empirical studies analyzed the negative social consequences of increasing consumption. Scitovsky, for example, introduced the "joyless economy" in his book of the same title in 1992 [33]. In their empirical study conducted during the period from 1981 to 1991, Jacobs and Worcester concluded that despite the rising incomes and growing consumption during the period under study, people were less satisfied than they were at the beginning of the study. Similar findings are found in recent contributions to happiness research. The feeling of happiness initially rises significantly with increasing prosperity, but only up to a certain per-capita income. After that, it stagnates or even drops off (15: 43).

Layard has also studied the relationship between income and happiness. He found that the level of happiness begins to stagnate at a level of income that approximates the levels reached in the poorer OECD countries ([24]: 53ff). He supports this finding with the fact that needs satisfaction is initially desirable up to a certain level. However, once that level is reached, increasing the standard of living no longer increases individual happiness. In this context, the obvious question to be asked is what then motivates our efforts to increase the level of income and the associated expansion of consumer choice.

Layard attributes this initial desire to relative position, that is, on the status of one individual over another member of society. Status is increasingly more important. The need for higher status establishes the social spiral in pursuit of a higher income, which, in principle, can go on indefinitely. The function of consumption as a means to securing basic needs is no longer an adequate explanation. Consumer goods increasingly function far beyond their material value so as to partly facilitate or enable us to participate in social life. These goods contribute to our prosperity on an intangible, i.e., a social level ([11]: 6). The higher income groups do not want to fall behind in terms of their social status and the middle and lower-income groups are striving to achieve a higher status or at least maintain their position in the status structure.

This phenomenon has long been relatively neglected in economics, although the American economist and sociologist Thorstein Veblen characterized it very well in 1899 in his book "*The Theory of the Leisure Class*." In it, he described the "conspicuous consumption" of the upper class of the United States. Consumption, according to Veblen, has only a demonstrative character: "Demonstrative consumption" describes a consumer behavior that goes beyond the satisfaction of primary needs [42]. The aim is to increase social prestige and has led to the creation of such terms as consumerists and consumerism.

A popular critique of consumerism by de Graaf, Wann, and Naylor equates it to "affluenza"—a disease of abundance, or "the illness of our time" [8]. Along these lines, Jackson sets boundaries to Sturn's idea, suggesting that we are not by nature inherently helpless idiots who are too lazy or too weak to resist the manipulative power of advertising. On the contrary, human creativity, emotional intelligence, and resilience are evident in desperate situations everywhere, even in the face of overtly pathological consumerism ([21]: 90). Nevertheless, Jackson also recognizes the tendency towards consumerism or affluenza.

Consequently, as part of his "double dividend" approach, Jackson quickly establishes the positive effect of reducing consumption in two ways: less consumption leads to greater well-being and makes a positive contribution to environmental conservation. He goes on to support the fact by citing the increasing chasm between consumption and needs satisfaction. "In pursuit of an inappropriate concept of progress, we are not only damaging our environment but also degrading our own psychological and social well-being" ([20]: 25).

The social dimension of sustainable development highlights the links between fair distribution and consumption. The estimates are that the richest 20% of the world's population earns 74% of the global income while the poorest 20% of the world's population earns a mere 2% of the global income. This situation represents not only extreme income inequality but also an unequal distribution of consumption possibilities. This leads to the situation that millions of people cannot satisfy their basic needs and others live in abundance.

Piketty suggests this presents itself as a humanitarian problem in various regions and leads to increasing social tensions [28]. Jackson responds with the question: "Can ever-increasing income continue to be the legitimate focus of the hopes and expectations of the already wealthy in a world of finite resources and ecological boundaries, a world still characterized by pockets of prosperity in the midst of an ocean of poverty? Or is there perhaps another fairer path to a sustainable form of prosperity?" ([21]: 4).

5 Support Opportunities for Sustainable Consumption

The demand and support for sustainable consumption is addressed throughout many agreements and documents at the international and national levels (see Sect. 3). Agenda 21 explicitly refers to sustainable consumption as an important element of sustainable development. The demand to analyze non-sustainable production and consumption patterns and to identify opportunities for change is expressed in the context of developing national strategies. Consumer habits can be influenced in many ways, making sustainable consumption a cross-cutting task that must be implemented in many areas of policy, including energy, transportation, waste management, and even in technology.

A major step toward specifying sustainable consumption was taken at the Johannesburg Conference in 2002 as part of the "10-year framework program on sustainable consumption and production patterns (10YFP)" (see also Sect. 3). The follow-on Rio + 20 Conference decided that actions should be implemented on a voluntary basis [25]. The basic priorities for action are as follows: Improve resource efficiency, decouple economic growth from resource use, and support access for developing nations to technical and financial aid for the implementation of sustainable consumption and production processes.

The complexity of the task is clear, for example, from a look at target 12.3 alone: "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses." According to FAO findings, the world throws away 1.3 billion tons of edible food annually. In Germany, 18 million tons or, roughly 30% of all food is wasted each year. If 10 million tons less food waste were produced, the cultivated acreage could be reduced by 2.6 million hectares. This equates to 15% of the total area now used to satisfy our need for agricultural produce. The EU and Germany, therefore, have established the goal to halve the amount of food waste by 2030. A similar situation occurs with the supply of medicine. Recent estimates assume that 10–50% of all medications are wasted. Taking just the lower estimate of 10% equates to an amount of 3.39 billion euro. In addition, the ecological costs are high, for example, water pollution caused by the disposal of medical waste ([11]: 34).

Germany passed a national program for sustainable consumption in 2016 [7]. The goal is to strengthen the ongoing efforts and initiate new measures to promote sustainable consumption. The program hinges on five key ideas:

– Make sustainable consumption a **feasible option** for consumers,
– Take sustainable consumption **out of the niche** and into the mainstream,
– Ensure **all** sections of the population **participate** in sustainable consumption,
– Look at products and services from a **life-cycle** perspective,
– Shift the focus **from products to systems** and from consumers to users.

An interdepartmental working group is responsible for the program and a competence center with the support and advisory role will be set up in the German Environmental Agency. Indicators are being developed to monitor the success of the program. The program has been received with considerable appreciation by experts. Deficits have been identified mainly in three areas:

(1) Incomplete identification of the relevant problem and fields of action,
(2) Inadequate formulation of appropriate measures, and,
(3) No budget was approved for the national program.

Absent in the national program for sustainable consumption is the key problem and field of action on "**food products of animal origin**" (meat, dairy products) has a substantial environmental impact. **Sufficiency** is another topic that receives too little attention with respect to changing consumer behavior and should have more relevance in the context of the affluent society. In addition to inadequate education on sustainable consumption, there is also a **lack of solid economic and regulatory measures**. For example, around €57 billion are still spent by the German state each year on environmentally harmful subsidies [39]. Also, the European Emissions Trading System EU-ETS has led to a considerable underpricing of environmentally harmful emissions due to a significant surplus of allowances. In addition, not all parts of the European economy fall under its regime; it only covers around 45% of the EU's greenhouse gas emissions.

As a result, not enough importance is attached to the **external costs** imposed on society. The situation could be improved, for example, by providing **monetary incentives** for sustainable consumption options over less sustainable ones. A positive example of this is the pricing of CO_2 mentioned earlier. A similar effect could be achieved by lowering the EU-ETS emissions cap, which would lead to higher emission allowance prices. The German Environment Agency (Umweltbundesamt, UBA) suggests a CO_2 price of at least €180 per ton, whereas the current price (mid-2019) ranges lower than €30 per ton ([38]: 8). Finally, in the German national program for sustainable consumption, there is an acknowledged lack of specific guidance provided on how to fund the proposed measures, therefore failure is pre-programmed [2].

6 Conclusion

Consumers' sovereignty is still an important paradigm in neoclassical economics. It is often seen as the foundation of liberty and fairness and, therefore, firmly anchored in modern economic policies. Consumers' sovereignty over as wide a range of goods as possible is also seen as the most efficient way to steer what is produced in an economy since consumption is the ultimate purpose of all production (from a market democratic perspective). Since (micro-)economists assume that needs are infinite, in principle, the demand for consumer goods (i.e., need satisfaction) knows no limits. Although consumers' sovereignty is a major good as viewed from the perspective of the consumer, it is often noted that individuals are not fully aware of their needs and the full range of available market choices and have no coherent preference system. Thus, their market choices often do not reflect their preferences, and, what is more, their preferences do not adequately reflect their wants. This, however, does not necessarily challenge consumers' sovereignty.

Consumers' sovereignty is based on the principle of individual differences. The societal consequences have long been ignored, for example, environmental pollution. Insofar as consumer-related environmental damage causes a society to suffer, consumers' sovereignty can be restricted or abolished, if need be, by the state. This has long been common for goods like prescription drugs, narcotics, or firearms, which can cause public health damage or endanger public safety. The European common market with good cause only allows products declaredly complying with standards for health, safety, and environmental protection. These regulations in fact assist consumers in their effort to consume sustainably by largely preventing harmful products from even coming on the market. In other cases, consumers may still be able to obtain harmful products (like biocides) but must use them cautiously and parsimoniously. However, consumers generally have the option to avoid environmental (and societal) damage and its cost by complying with environmental regulatory standards. This conveys a social dimension to consumption; for example, consumption must not limit the general welfare of the society, for example, by contributing to environmental pollution.

The relationship between conventional consumption and material welfare is positive. Analogously, the relationship between sustainable consumption and societal well-being is positive. Therefore, sustainable consumption does not pose an impediment to society's well-being, quite the contrary. Agenda 21 consequentially includes the call for sustainable consumption. The starting point was the need to change consumer habits, specifically, to deal with unsustainable consumer patterns. It further provided a distinction between the intent and the effect of sustainable consumption: an individual must have both an intention to consume according to the standards of sustainable development and to achieve a lasting effect with that choice. The following areas are particularly well-suited for sustainable consumption practices: mobility, food, habitation, clothing, and electronics (see Sects. 3 and 5).

At the international level, Agenda 2030 takes on greater importance with its 17 sustainability goals. It applies to all nations of the world and provides specific targets.

SDG 12 calls for sustainable production and consumption patterns that will enable the change to a way of life and an economy that respects the Earth's natural limits. The achievement of sustainable management and more efficient use of natural resources as well as halving the world's per capita food waste are specifically required for the implementation of the 10-year framework program for sustainable consumption and production.

The specifics of the sustainable consumption concept can be further developed. However, the real problem rests with the implementation, which is facing a series of obstacles. For example, the deeply rooted freedom of choice in consumers' sovereignty is still of great importance today for many people. The rising income levels in many countries also contribute to an increase in consumption and, ultimately, strong path dependencies on long-cultivated consumption patterns. The societal consequences of consumption were recognized at an early stage, above and beyond the negative ecological effects. At some point, rising consumption no longer contributes exclusively to satisfy a need, but aims to increase status. Subsequently, consumer goods increasingly go far beyond their material value, by making it easier or possible for people to participate in social life. Terms like consumerism were introduced to describe this phenomenon.

Calls for sustainable consumption are being heard at international and national levels. A major step toward specifying sustainable consumption was taken at the Johannesburg Conference in 2002, where the "10-year framework program on sustainable consumption and production patterns (10YFP)" was developed. The implementation is to be achieved on a voluntary basis. The key priorities are as follows: Improve resource efficiency, decouple economic growth from resource use, and support access for developing nations to technical and financial aid for the implementation of sustainable consumption and production processes. Germany passed a national program for sustainable consumption in 2016. The program addresses major fields of action. However, the document has shortcomings in how it addresses them, for example, a key field of action is omitted and implementation measures are rather vague.

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Public Health: A Political Toolbox to Reduce Violation of Earth

Hans P. Zenner

Abstract Modern medicine consumes considerable resources of the Earth. This has indirectly contributed significantly to the violation of Earth. Resource-consuming examinations, however, and therapies for diseases can be reduced by prevention. Thus, with the prevention, an indirect contribution to the reduction of injury to the Earth can be achieved. If prevention takes place at the macro level, millions or even billions of people can be addressed at the national or international level simultaneously. Public and global health science options include non-communicable disease prevention, management of infectious disease outbreaks, national and international long-term disease detection, and the timely absorption and translation of cutting-edge health-related research and technology results. Thus public and global health science may provide powerful scientific levers to reduce the use of Earth's resources by modern medicine and thus reduce the indirect violation of Earth by modern medicine.

Keywords Public health · Resource use · Disease prevention · Health impact assessment · Medical expenses

1 Introduction

Modern medical examination methods and medical therapies for diseases of billions of patients consume considerable resources of the Earth. Due to the current prevalent methods of resource provision, the enormous expense of a successful modern medicine has indirectly contributed significantly to the violation of Earth. Ethically, the use of resources of the Earth may be justified for adequate evidence-based medicine: consumption of Earth resources contributes to human well-being in the context of restoring human health, dignity and autonomy. According to Article 25 of the Universal Declaration of Human Rights of the United Nations of 1948, health is a fundamental human right.

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2 Problem Situation

In principle, however, resource-consuming examinations and therapies for diseases can be reduced by prevention. Prevention is suitable for influencing the development and course of diseases in such a way that the complex procedures of modern medicine may be required less frequently. Thus, with the prevention, an indirect contribution to the reduction of injury to the Earth can be achieved.

Medicine operates prevention, but typically only at the micro-level, i.e. in the setting of physician and individual ill. For prevention, however, it is better to reach people before they get sick. Moreover, if prevention does not take place at the micro-level but at the macro-level, millions or even billions of people can be addressed at the national or international level simultaneously.

The corresponding science is not about medicine but about public or global health. Public or global health has the task of providing the scientific basis for influencing society so that society as a whole or target groups in the society are empowered to prevent [1, 5, 11, 13–15]. Public health science options include non-communicable disease prevention, management of infectious disease outbreaks, national and international long-term disease detection, and the timely absorption and translation of cutting-edge health-related research and technology results. National public health cannot be thought of without global health, because diseases overcome national borders. This requires a pro-active attitude of national public health toward the global dimension [3, 7, 10].

Because public health can contribute to disease prevention at the national level for millions of people, globally even for billions of people [8] it may provide powerful scientific levers to reduce the use of Earth's resources by modern medicine and thus reduce the indirect violation of Earth by modern medicine.

On the basis of evidence-based findings, it may be the task of public health, inter alia, to advise policymakers on using political instruments to enforce prevention [2, 9]. A typical example is the obligation to vaccinate. Further examples are the reduction of cardiovascular diseases, obesity and smoking prevention, and occupational safety. In addition, an important aspect of modern public health can be to take into account the health of the population in view of all legislation issues (*Gesundheitsfolgenabschätzung*) and to advise policymakers. However, with regard to public health's task of advising policymakers how to use powerful public health levers to prevent disease and thus to reduce violation of Earth, it is striking that communication between politics and academic public health is neither sufficient nor robust [4, 12]. From a specific German point of view, it must also be regretted that national public health in Germany has hardly any global appeal. According to a recent analysis [6], the most productive countries (by a total number of publications) are the USA (42,958), UK (13,663), Canada (6,723), Australia (6,202), Brazil (5,343), The Netherlands (3,926), Sweden (2,516), and Spain (1,709). These leading countries are followed by Germany (n = 1,604) at position nine. The same may be found in the field of epidemiology [6] with the USA (n = 28,889) at position one and Germany (n = 2,531) no better than at position eight. This notwithstanding, national public health in Germany too often takes place without the expertise of physicians.

3 Recommendations

These insights result in recommendations, as also partly reflected in the recommendations of the German National Academy of Sciences Leopoldina [6]:

1. Inclusion of significantly more physicians in the national public health system of the Federal Republic of Germany. Public health without a sufficient number of doctors is public health without a future. This includes first of all the education and training of physicians with the goal that doctors operate public health. On the other hand, communication training of non-medical public health specialists is required in order to enable them to perform interdisciplinary communication between their specialty and medicine. At the same time, appropriately trained physicians must be available from the medical side so that the bridge between preventive and therapeutic medicine on the one hand and preventive public health on the other hand can be erected robustly, permanently and sustainably, in particular between medical scientists and non-medical scientists.

2. It is not uncommon for the full impact of public health's results to be achieved only if accompanying political actions are implemented, for example in the form of laws or regulations. This requires a sustainable and robust communication bridge and translation between public health and politics. For this purpose, the National Academy of Sciences Leopoldina has proposed a corresponding national institution for "public and global health" in Germany, which should bundle public health results at the national level and global level and should provide a stable bridge to politics and its necessary decisions.

3. Another recommendation is the promotion of public health at the academic level by universities and institutes, municipalities, federal states, and federal government. Without exception, this should include medicine in the form of physicians in the area of public health and in the form of institutionalized bridges allowing translation between medicine and non-medical service providers in public health.

4. Policymakers should use evidence-based results of public health as a powerful toolbox for political interventions to prevent diseases as one of their contributions to a reduction of the violence of Earth.

4 German Translation

4.1 *Einleitung*

Moderne medizinische Untersuchungen und Therapieformen von Krankheiten von Milliarden von Patienten verbrauchen beträchtliche Ressourcen der Erde. Aufgrund der gegenwärtig vorherrschenden Methoden der Ressourcenbereitstellung hat der enorme Aufwand einer erfolgreichen modernen Medizin mittelbar wesentlich zur Verletzung der Erde beigetragen. Ethisch kann der Verbrauch von Ressourcen der Erde für eine angemessene evidenzbasierte Medizin gerechtfertigt sein: der Verbrauch trägt zum Wohl des Menschen im Zusammenhang mit der Wiederherstellung von Menschenwürde und Autonomie bei.

4.2 *Problemlage*

Grundsätzlich jedoch können ressourcenverbrauchende Untersuchungen und Therapien von Krankheiten durch Prävention vermieden werden. Prävention ist geeignet, die Entstehung und den Verlauf von Erkrankungen in einer Weise zu beeinflussen, dass die aufwendigen Verfahren der modernen Medizin seltener angewendet werden müssen. Damit kann mit Prävention ein mittelbarer Beitrag zur Reduktion der Verletzung der Erde geleistet werden.

Medizin betreibt Prävention, typischerweise jedoch nur auf der Mikroebene, also im Verhältnis zwischen Arzt und individuellem Kranken. Für eine Prävention ist es freilich besser, die Menschen bereits zu erreichen, bevor sie krank werden. Findet Prävention zudem nicht auf der Mikroebene, sondern auf der Makroebene statt, so können auf nationaler Ebene gleichzeitig Millionen oder international Milliarden von Menschen angesprochen werden.

Bei der korrespondierenden Wissenschaft handelt es sich nicht um Medizin, sondern um Public Health. Public Health hat die Aufgabe, die wissenschaftlichen Grundlagen zur Beeinflussung der Gesellschaft zur Verfügung zu stellen, damit die Gesamtgesellschaft oder Zielgruppen in der Gesellschaft Prävention betreiben. Die wissenschaftlichen Optionen von Public Health umfassen Krankheitsprävention, das Management von Infektionskrankheitsausbrüchen, nationale und internationale Langzeitkrankheitserfassungen und die rechtzeitige Aufnahme von gesundheitsrelevanten Ergebnissen aus Forschung und Technologie. Public Health kann auf nationaler Ebene zur Krankheits-Prävention bei Millionen von Menschen, global bei Milliarden von Menschen, beitragen. Damit ist Public Health ein mächtiger wissenschaftlicher Hebel, die Erdressourcennutzung durch die moderne Medizin zu verringern [8] und damit die mittelbare Verletzung der Erde durch die moderne Medizin nachhaltig zu reduzieren. Auf der Grundlage entsprechender wissenschaftlicher Erkenntnisse kann es in diesem Zusammenhang Aufgabe von

Public Health sein, unter anderem die Politik zu beraten, politische Instrumente zur Durchsetzung von Prävention zu verwenden [2].

Typisches Beispiel ist die Impfpflicht. Weitere Beispiele sind die Reduktion cardiovaskulärer Erkrankungen, Fettleibigkeit, Raucherprävention und Arbeitsschutz. Ein wichtiger Aspekt moderner Public Health kann es darüber hinaus sein, die zu berücksichtigende Gesundheit der Bevölkerung bei sämtlichen politischen Fragestellungen in den Blick zu nehmen und die Politik zu beraten. Dabei kann nationale Public Health ohne Global Health nicht gedacht werden, denn Krankheiten überwinden nationale Grenzen. Dies erfordert eine proaktive Einstellung einer national gedachten Public Health für die globale Dimension [3, 7, 10].

Mit Blick auf die Aufgabe von Public Health, die Politik zu beraten, mächtige Hebel zur Krankheitsprävention und damit zur Reduktion der Verletzung der Erde zu verwenden, fällt jedoch auf, dass die Kommunikation zwischen Politik und akademischer Public Health weder suffizient noch robust ist [4, 12]. Aus deutscher Sicht muss zudem bedauert werden, dass die nationale Public Health in Deutschland kaum globale Ausstrahlung hat. Die 10 produktivsten Länder (nach Gesamt-Publikationszahl) sind die USA (42.958) > Großbritannien und Nordirland (13.663) > Kanada (6.723) > Australien (6.202) > Brasilien (5.343) > die Niederlande (3.926) > Schweden (2.516) > Spanien (1.709) > Deutschland (1.604) > Frankreich (1.508). Auch findet nationale Public Health in Deutschland zu häufig ohne Ärzte statt.

4.3 Empfehlungen

Daraus ergeben sich Empfehlungen, wie man sie auch in den Empfehlungen der nationalen Akademie der Wissenschaften Leopoldina[1] wiederfindet:

1. Einbeziehung von deutlich mehr Ärzten in das nationale Public Health System der Bundesrepublik Deutschland. Public Health ohne eine ausreichende Zahl von Ärzten ist Public Health ohne Zukunft. Dies umfasst zunächst die Edukation und das Training von Ärzten mit dem Ziel, dass Ärzte Public Health betreiben. Zum anderen bedarf es einer Ausbildung und eines Trainings nicht ärztlicher Public Health Spezialisten, um sie in die Lage zu versetzen, die interdisziplinäre Kommunikation zwischen ihrer Spezialität und der Medizin zu leisten. Zugleich müssen auch von medizinischer Seite entsprechend ausgebildete Ärzte zur Verfügung stehen, damit die Brücke zwischen präventiver und therapeutischer Medizin auf der einen Seite und präventiver Public Health auf der anderen Seite insbesondere zwischen ärztlichen Wissenschaftlern und nicht ärztlichen Wissenschaftlern robust, dauerhaft und nachhaltig geschlagen werden kann.
2. Die vollständige Wirkmacht der Ergebnisse von Public Health kann sich nicht selten nur entfalten, wenn begleitend politische Aktionen etwa in Form von Gesetzen oder Rechtsverordnungen umgesetzt werden. Dazu bedarf

[1] Leopoldina [6] Public Health in Deutschland. Halle.

es einer nachhaltigen und robusten Kommunikationsbrücke und Translation zwischen Public Health und Politik. Hierzu hat die nationale Akademie der Wissenschaften Leopoldina eine entsprechende nationale Einrichtung für „Public and Global Health“ in Deutschland vorgeschlagen, die Public Health Ergebnisse auf nationaler und globaler Ebene bündeln soll und eine stabile Brücke zur Politik und ihren notwendigen Entscheidungen darstellen soll.

3. Eine weitere Empfehlung ist die Förderung von Public Health auf akademischer Ebene durch Hochschulen und Institute, Kommunen, Länder und Bund. Und zwar ausnahmslos unter Einbeziehung der Medizin in Form von Ärzten im Gebiet Public Health sowie in Form von institutionalisierten Brücken zur Translation zwischen Medizin und nicht medizinischen Leistungsträgern in Public Health.
4. Die Politik sollte evidenzbasierte Ergebnisse der öffentlichen Gesundheit als Instrumentarium für politische Interventionen zur Verhütung von Krankheiten als Beitrag zur Verringerung der Verletzung der Erde nutzen.

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Enlightenment 2.0: Toward Responsible Science in the Anthropocene

Markus Vogt

Abstract The following essay reassesses ethical aspects of the relationship between science and society. What we need in the situation of climate change are new models of transdisciplinary, dialogic, public, and transformative science. The centerpiece of this model is an integral assignment of knowledge and responsibility. They understand ethical questions and social transformation as integral components of scientific research and rationality. This means nothing less than a new phase of enlightenment in favor of the idea of embedded knowledge and a different understanding of progress, freedom, and welfare. The program of such an "Enlightenment 2.0" for a full and ecologically fragile world is not an expansion of power, but rather a taming of power in the interest of global and intergenerational fairness. The challenges of climate change and the environmental crisis require an intelligent self-limitation as well as a reorientation of innovation dynamic geared toward sustainability and resilience. The danger of manipulation of public opinion in the digital age demands science as an active effort to provide society with reliable information and to maintain standards of rationality. In the face of massive injustice and public contempt for reason, science cannot take an ethically neutral and uninvolved position. Responsible science is a crucial part of enlightenment in the Anthropocene.

Keywords The end of the modern age · Anonymization of power · Transformation of concepts for progress · Enlightenment for a full world · Transformative science · Concepts of rationality · Cultural revolution · Role of religions

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1 The End of Modern Times

The philosopher of religion, Romano Guardini (1885–1968), divides history into three basic epochs: In Antiquity, he argues, it was a matter of finding the image of the well-made man and the noble work as an expression of the universe's inherent harmony. The concept of classical humanism was developed. The Middle Ages experienced the relationship with the supernatural God in a special way, which served as a source for its power of an upswing, a way of life that was, for example, materialized in its Gothic cathedrals. It wanted to order its existence as granted by a superordinate authority. The Modern Age experienced hitherto-unknown proximity between the mind and physical reality through its technical access to the world. The determining force of this epoch was gaining power over nature and taking possession of things (cf. Guardini [8: 97f, 147, 30–46]). The Modern Age had essentially ended, still overlaid by further expansion of power, but striving for an expansion of power was no longer meaningful [8: 47–79]. The use of the nuclear bomb in Hiroshima is decisive for this new awareness of the ambivalence of power.

> For the coming epoch, the last thing is no longer about increasing power, [...] but about taking it. The central point of the epoch will be the task of classifying power in such a way that man can exist in its use as man. [8: 98][1]

Guardini's analysis of the end of the Modern Age, published in 1951, is confirmed by the environmental and climate crisis of the present in a way that was hardly foreseeable at the time. Some parts of the world society are already drifting toward their ecological and socio-cultural tipping points. We must prepare ourselves to cope with phenomena of collapse and disruptive processes of change [2, 17: 21–60]. Geology most dramatically summarizes the diagnosis of the situation together with the thesis that we have entered a new epoch of the Earth's history: the Anthropocene. According to this concept, the relatively stable state of the ecological system of the Holocene, in which *homo sapiens* has developed over the last 11,500 years, has come to its end [9, 12]. What the new dynamics of the Earth system will look like, we do not know. We only know that we are transitioning toward other patterns of energy and material flows on Earth that will severely change the human habitats on this planet. The diagnosis of the Anthropocene radicalizes Guardini's thesis of the end of the Modern Age: a radical reorientation of its guiding values is necessary so that it does not completely lead to destructive dynamics.

Therefore, the *leitmotif* of the expansion of power over nature that has been so successful in the past 500 years can no longer be a meaningful maxim. The expansive Modern Age has come to its end. It destroys its own foundations of life. The wounded Earth strikes back and hurts the human being. For he is dependent on the habitats he destroys. Through the socialization of environmental problems, ecological problems become social problems at the same time. There is not one environmental crisis alongside a social crisis, but only one eco-social crisis, as pope Francis notes in his Encyclical Letter Laudato sì [20: FN 139].

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[1] All citations translated by the author.

Our present, however, is still largely shaped by the normative guiding ideas of expansive modernity. It is determined by the idea of universal plannability. Material and energy in nature, but also man himself, become the object of planning. They are estimated and managed with statistical methods. Serious reasons advise on this kind of planning: a political necessity as well as an increase of economic goods and requirements of correct distribution [8: 143]. "If nature is progressively dominated by man and his work, then man himself is also dominated by the other man, who classifies him" [8: 133]. Like human capital, people seem to be arbitrarily replaceable and ready for the grasp of power in economy and administration, whereby cultural differences are leveled out—not least by standardized forms of rationalization and functionality. Science as a rational grasp of the real, and technology as domination made possible by science are in the foreground and give the present epoch its character (cf. Guardini [8: 131]).

According to Guardini's diagnosis of time, the expansion of power is about to tip over into its opposite: instead of man dominating power, the inherent dynamics of his technological products, and the anonymous force of the complex system logics of the social sub-areas increasingly determine him. The externalization of power has gained a momentum of its own, through which man ceases to be a subject in history in a comprehensive sense, but is more often a mere transit point for processes that lie beyond his reach (cf. Guardini [8: 167]).

2 Regaining Power Over Power

While modern times were determined by the attitude toward life of a never-measurable being and inexhaustible reserves, the feeling that our world is limited and endangered is gaining the upper hand in the present [2, 12, 16, 29, 32]. It seems obvious that climate and environmental crisis in the Anthropocene can only be solved with a profound change in the ideas of progress and prosperity. A comprehensive and rapid change in values and culture has become a prerequisite for the necessary transformation. The program of the future is not expansion, but rather a taming of power in the interest of global and intergenerational fairness. It is about a changed mindset of responsibility and mindfulness. Characteristic of this new epoch is a consciousness of wholeness that does not look at things and processes as isolated entities but considers their interactions as decisive (cf. Guardini [8: 156f, see also the concept of holistic ecology in the Encyclical Letter Laudato sì No. 137–162; [2]). One can paraphrase this concept of taming power as "Enlightenment 2.0" [32: 181]. The goal is a raised awareness of the ecological and cultural embedding, context, and conditions of progress and rationality.

Guardini's analysis of the end of the modern era is linked to the hope of a new type of human being in the making. One who does not fall prey to the powers that have been set free, but is able to order them, reclaims power over his own power and puts it into service for the human being [8: 168]. The meaning of the coming culture is not an increase in welfare, but domination in a radical and original sense. Not power with a guilty conscience hidden behind the goals of security, utility, welfare, and consumption, anonymized and shifted to these goals, but real rule in the sense of the cultural self-determination of man from human values. A prerequisite for this is to develop a sense of asceticism. No greatness is based on overcoming and renunciation. It is necessary to rediscover the liberating power of overcoming oneself [8: 172]. A genuine metanoia is required: man cannot withdraw into any laws, neither of nature nor history, but must himself stand up, and therein lies the chance of the future. It is about an attitude of commitment to justice and the will to see the way things are and to do what is right from there [8: 163]. One can also describe this attitude as concern and willingness to take responsibility.

At the heart of the search for a sustainable ethical compass—in the face of current upheavals—lies the relationship with nature. It requires a critical reflection of a spreading naturalism that makes the values of nature absolute and idealizes the equilibrium supposedly found in nature; for example, as the basis of a shortened understanding of sustainability [28: 216–372]. Evolution is an order that constantly develops through conflict and states of non-equilibrium. Justice cannot derive from it. This also applies to the category of sustainability that explicitly understands itself as global and intergenerational justice. However, it is often exaggerated as a secularized promise of salvation. The longing for harmony between ecological, economic, and social goals rhetorically softens the conflictual nature of an earnest sustainability policy.

Recovery of power over power requires quite substantially a sober analysis of the material and power conflicts on the path to achieving more sustainability. It needs transformation research as a search for differentiated knowledge of how change happens in complex systems and how it can be controlled, influenced, and accelerated. The time window for the necessary change *by design*, instead of change *by disaster*, will close very soon [2, 17, 25]. Against this background, Enlightenment 2.0 also includes the encouragement to resist the blind momentum of social subsystems and massive power interests that are blocking the necessary change. It understands the freedom of science as an obligation to respond and to a power of judgment independent of the respective power interests.

3 Enlightenment for a Full World

The sciences undoubtedly play a key role in the necessary intellectual and cultural reorientation. They are the driving force behind the essential transformation in a knowledge society. At the same time, a considerable part of the current scientists research and teach precisely along with the paradigms that drive societies further into the aimless "higher, faster, further" of expansive modernity. They themselves must practice the change in thought and action they wish others to make. The phenomenon of the "raging standstill" can often be observed in the universities themselves: With a lot of stress under the maxim of constant productive *output* in examinations and publications, there is little time to think thoroughly about leisure and to look beyond the axioms and paradigms of one's own subject. That is exactly what it would take.

The discourse on sustainability leads to a philosophical and scientific theoretical reflection on the epistemic and ethical–political foundations of the project of modernity, which have become fragile and need further development. It will be important not to abandon human rights universalism, but at the same time, to become more sensitive to cultural contexts and ecological preconditions that are often decisive for its specific perception. Equally important is a critical revision of the notions of rationality, space and time, freedom, and political control that underlie the project of modernity.

Ernst Ulrich von Weizsäcker and Anders Wijkman postulate an "Enlightenment 2.0" [32: 181], which they characterize as Enlightenment "for a full world." At its core lies a methodically controlled reflection on the epistemic and normative premises of every science, including the supposedly value-free ones. Fundamental for the success of such a transformation is a new quality of scientific dialogue between natural sciences and humanities that has grown into "two cultures" over many decades [24]. Elucidation of the preconditions and limits of the different models of rationality in the sciences is the decisive impulse for interdisciplinary discourse (cf. as an "alternative to the history of disenchantment" in discussion with Max Weber and Ernst Troeltsch: [13], as well as an attempt to reinterpret Max Weber along with the guiding concept of "enlightening rationalization": [10]). The awareness of their institutional embedding—that always presupposes certain perspectives—strengthens a self-critical distance. The allocation of empirical, normative, and transformative components of knowledge must be reflected upon in a new way if science is to promote not only factual knowledge but also competence in judgment and action [7, 14, 15, 23].

However, a profound dilemma arises in the classification of basic, orientation, and action knowledge: we live in a knowledge society that depends on innovative research to solve the problems it generates; the associated risks and side effects can—ex-ante—only be calculated to a limited extent [21]. The processes of knowledge generation are open and require a fundamental trust in problem solutions that are yet to be developed. Discourses of risk and responsibility often tend to be defensive and alarmist in order to be heard. At the same time, there is a wealth of systemic and creeping risks that are often perceived belatedly (such as the loss of biodiversity). We must learn to fear the right thing and proactively take responsibility as a compass for open design processes rather than as discourses of moral chapels. We require ethics as part of science education and research, not only in the context of commissions that review specific problematic applications of technology or new medical knowledge.

One way of implementing such an "Education 2.0" at universities would be a philosophical and epistemological examination of the fundamental models of the respective subject at the beginning of all study courses. Every course should begin with concept training, learning to think, and an explanation of the normative premises of the subject-specific guiding models. Such an approach promotes responsibility *in* the sciences and humanities instead of referring ethics to a role as a subordinate "spoilsport authority" that only raises its index finger in critical applications. The concept can also be described as education for sustainable development. It conveys the basic principles of dealing with complex systems, comprehensively introduces the philosophy of recycling management, bio-economy, and sustainable management, and enables active participation in shaping democracy.

4 Transformative Science

The relationship between science and society is currently being reassessed. There is a demand to rethink knowledge and responsibility as well as freedom and autonomy. Various header label the respective debate (see Grunwald [7]; Vogt [30: 13–17]), e.g. "transdisciplinarity," "public science," "citizen science," a "dialogical" and "integral university system," "third mission," "transformative science," "research with social responsibility," "sustainability in science," or "oppositional and emancipatory science." Among them, the programmatically most controversial and therefore particularly suitable term for a conceptual debate is "transformative science."

The normative claim of transformative science is an attack on the positivist philosophy of science. Morally, this theory is connected with a profound dilemma: By reducing the understanding of reason to its acknowledging function, it necessarily surrenders itself to the morality of subjective decisions and purposes that are open to arbitrariness. It becomes a means to goals, which ultimately does not define itself. In positivism, morality is understood as a question of subjective preferences that cannot be further substantiated and is thus excluded from the concept of science (on the highly complex positivism dispute in philosophical ethics cf. [1, 11, 14, 15]).

The positivist understanding of science dominating the last century differed strictly between the supposedly objective and value-free determination of facts on the one hand and the evaluation of this knowledge on the other. It must be critically developed further and partially revised concerning the prerequisites and embedding contexts of supposedly value-free research [10, 15, 32]. For Horkheimer and Adorno, the separation of value and research in conventional social science thinking, according to which the practical use of the conceptual systems and thus one's own role in practice is to be regarded as external to the research process, produces a blind spot of lacking self-reflexivity. It hides the structural preconditions and consequences as well as the perspective of scientific positions behind the appearance of neutrality instead of making them transparent (cf. Horkheimer [11: 182]). At the same time, this would undermine the necessary distance from the regulatory system of society, which has solidified in science (cf. Adorno [1: 299]).

The science-policy search for a changing role of universities in society wants to make use of them as not only observers but also more strongly as "change agents." It is the core problem of the concept of sustainability in the theory of science: This concept has established itself above all in the political sphere and is initially a socio-political and not a scientific concept. Sustainability is a discourse of responsibility whose strong normative charge in its depth structure fits by no means with common notions of freedom, autonomy, and scientific excellence at universities. Its integrative claim is at odds with the process of increasing differentiation. It is feared that scientific freedom is claimed for ethical and political goals and thereby sacrificed [26]. The old question of whether science can content itself with thinking the world, or whether it should also directly strive to change the world, is posed with new urgency in the context of the existential self-endangerment of society in the context of climate change.

In this situation, the retreat to an ethic of supposed neutrality and abstention amounts to participation in the system that produces injustice and destroys the future.

> A science that, in imagined independence, regards the shaping of the practice to which it serves and belongs merely as its afterlife, and that separates thought and action, has already renounced humanity. [11: 216]

In the face of massive injustice, science cannot take an ethically neutral and uninvolved position: "Because we live in an unjust world that is worthy of criticism, there is no neutrality" [15: 19]. The denunciation of engagement as heteronomous amounts to a structurally conservative conformism of thought [15: 42f]. Here, the error in thinking is the sequential conception of science as a self-contained space on the one side, and of politics or the public as a downstream field of application and intervention on the other side. However, especially science dealing with the production of symbolic goods is confronted with ethical–political questions from the very beginning:

> The assertion that intellectual engagement amounts to the confrontation with an ethical question and that the form of our theoretical work must be determined on the basis of the world and the action it generates in it means that one cannot accept and adopt the established forms and institutions of scientific and cultural practice, only to ask oneself in a second step how one can contribute to changing the world. Rather, one must start out from the necessity of an emancipatory production of knowledge and then ask oneself what understanding of one's own life as an author, of practice and theory follows from this. In order to determine the form of our actions, we must start with an ethical concern. The political question arises *ex ante*, not *ex post*. [15: 16f]

The suspicion that the rhetoric of usefulness might subject science to utilitarian thinking is quite justified. However, there is a misunderstanding if this usefulness is considered a downstream application, after having previously placed the autonomy of science in a kind of "mysticism of pure knowledge" [15: 26] outside the sphere of society. Lagasnerie compares the understanding of science as "*l'art pour l'art*" with the idea of profit for the sake of profit. It is "a kind of ethics of withdrawal, of depoliticization, which gives a potentially subversive activity a social and political harmlessness and thus enables the reproduction of the existing order and its basic values" [15: 33]. The insistence that science is a fixed profession, a self-contained realm within the social whole, reveals the very essence of thinking (cf. Horkheimer [11: 216]). It bases on a naïve understanding of the complex nexus of theory and practice and fails to recognize that science is always a form of practice. If one locates usefulness in this original link between theory and practice, it is not an out-of-scale utilitarian evaluation of consequences but represents an inherent moment in the practice of knowledge.

The science of sustainability implies profound divergences to the cornerstones of the current social model, in particular to growth, feasibility/controllability, and individual freedom. There is a need for clarification here that equally concerns the foundations and concepts of rationality, and the normative guiding concepts of society. This situation requires new forms of dialogue between science and society [7]. Ultimately, it is by no means just a matter of pragmatic challenges in the context of climate change but rather of the fundamentals of the understanding of science.

5 The Erosion of the Ideal of Freedom from Within

Late modernity is characterized by the fact that power is often made anonymous and seems to hide behind unfathomable chains of action. A peculiarly empty space is created in the action [8: 106]; for illustration the author refers to Kafka's novels "The Trial" and "The Castle". The awareness spreads that ultimately there is no one acting, but a sequence of events determined by an indeterminacy that cannot be grasped anywhere, that does not pose itself to anyone, and does not answer to any question [8: 106]. This anonymization of power has become a characteristic feature of the current economy, especially through the global chains of action in the world financial markets.

Quite a few fear that the ideal of freedom of liberalism will perish in the intrinsic logic of economic and political systems because freedom is confused with market freedom, while responsibility becomes lost in system imperatives that are supposed without alternative. The consequences are far-reaching. The American political scientist Patrick Deneen concisely summed this up in his internationally discussed book "Why liberalism failed" [5: esp. 15–27]. According to his diagnosis, the transnational universalism of ethics has come to its end because the elites in politics and business are exploiting their greater opportunities for freedom unilaterally for their private advantage. The normative basis of an open democratic society, namely the interplay of responsibility and freedom has been abused and systemically undermined. Renationalization is the inevitable answer to this.

Thus, the social embedding and legitimation of modern science as part of the transnational elite system seems fragile. Universities and colleges in some countries already feel the effects on a massive scale. A deep mistrust of academic elites is reflected in populism worldwide, and becomes a political force within it. It is obvious, however, that neither the nationalist narrow-mindedness of responsibility nor the authoritarian anti-liberalism offer ethically viable paths. World society is losing sight of the moral and cultural foundations of social cohesion. There is no consensus regarding the interplay of freedom and responsibility under the conditions of disruptive transformation processes in an increasingly polycentric world.

Climate change presents the idea of freedom with enormous challenges. In a society that has banned the idea of collectives, it is challenging to think about the collective structure of climate responsibility. An individualistic narrow concept of freedom and responsibility that loses sight of its cultural and institutional contexts fails because of the complex structure of the chains of action and causation found in climate change.

Today, freedom and reason as guiding values of modern Western societies must prove themselves by empowering to manage the complex problems of responsibility in the Anthropocene. This particularly applies to science, which can only develop its potential under the condition of fundamental trust in the reason of freedom. Science must defend societal trust in reason and freedom as the basis of democracy by proactively taking responsibility for coping with the central challenges of society. It must not hide behind the non-binding nature of a systemic, ultimately questionable concept of freedom and stand idly by watching its structural incapacitation in many countries. It must become more political. Strengthening the voice of science in the context of political decision-making processes improves the chances of responsibility. However, it is by no means—as the criticism of the model of transformative science discussed above formulated it—an "atrophy of the political." On the contrary, it is a necessary contribution to saving the political under the conditions of modern knowledge societies.

The Enlightenment came to power with the idea of freedom. At present, this ideal seems to have become strangely pale and weak. For fear of terrorism and uncontrollable social development, or for the sake of pragmatic advantages in the digital society, many liberties are carelessly abandoned or undermined. Enlightenment 2.0 means a strong plea for freedom by combining it with responsibility [27]. Abandoning freedom for the sake of supposedly authoritative security would be a regression behind the achievements of the Enlightenment.

6 Uncertain Confidence in Reason in the Digital Age

Mrs. Conway, US President Trump's consultant, speaks of "alternative facts." This is an attempt to suggest that in the end, it is not about what is happening, but only about the clash of different opinions, some of which prevail and some of which do not. This is precisely a crucial strategy in the fight against the uncomfortable environmental-ethical claims in the context of climate change: one tries to get rid of them by questioning the reality content of the underlying perceptions of reality. Such doubts are by no means only found among Trump and other climate skeptics paid for by the oil industry [22]. With the worldwide "March for Science," scientists have protested against the fact that scientific findings are not being taken seriously enough in many areas of societal future planning.

Julian Nida-Rümelin diagnoses a connection between the refusal to take note of scientific facts relevant for action and the "ideology of anti-realism:"

> Politically powerful people have at all times tried to keep facts secret, to influence, manipulate and falsify them with unverifiable assertions. What is new is that they use the ideology of anti-realism in its postmodern and poststructuralist variants. [18: 33]

These politicians try to give the impression that there is no reality, only opinions conveyed by the media. The new digital media are cleverly used to reinforce this impression. In fact, a great many people seem to form their opinions in digital "bubbles" that immunize against criticism because they only select and reinforce what fits their own preconceptions. This dynamic is politically highly dangerous and explains the deep insecurity behind the superficial political excitement about the rhetorical phenomena of the post-factual. The uncertainty of communication in the age of digital manipulation of opinion demands of the sciences an active effort to provide society with reliable information and to maintain standards of rationality.

Within journalism, there is a structural parallel to the scientific-theoretical debate on the question of whether journalism should maintain its professionalism in the role of a distanced observer or whether it should show stronger commitment as "transformative journalism" [19]. Due to the logic of attention-maximizing, journalism tends to report the news rather than fundamental problems, despite all reports on climate change. The power of those in power to define the possibilities and limits of discourse means that the deeper causes of climate change, which call into question current thought patterns, guiding values, and social systems, tend to be repressed. With all the efforts to create a new "framing" and attractive narratives of environmental journalism, there lies a danger to end up confirming thinking patterns that are more wrapped up in green. Despite all criticism, however, it should not be overlooked that there are high-quality standards in journalism, at least in most European countries, which also include transformative elements. There are many reasons why short-term "hyped" topics tend to dominate in the public sphere, especially in times of election campaigns, and why climate change is, therefore, rarely given the attention it deserves in ethical terms.

Concerning ethics, it is also a question of whether the normative reason is merely a convention and a question of subjective preferences, or whether it is suited to a scientifically accessible truth content. Nida-Rümelin illustrates this with the question of whether the Holocaust was objectively morally wrong or whether its rejection should only be considered a culturally variable convention [18: 82]. If one assumes that ethics has a content of truth that is also scientifically sound, then it will be sometimes uncomfortable and must not become too dependent on public opinion.

The contempt for expert knowledge in the post-factual age is a challenge that scientists cannot silently accept, if only for reasons of self-respect. The contempt for reason undermines the foundations of our culture. Equally destructive of culture are self-generated systemic constraints that prevent politics, business, and society from reasonable choices. With good reason, one should expect more resistance from academics against the post-factual populist mockery of reason, and the relapse into a nationalistically fragmented narrowing of horizons. Such a state of knowledge is the necessary answer of enlightened and enlightening science to the relapse of parts of public communication into a "post-factual" immaturity. The new phase of enlightenment is characterized by the courage to accept uncomfortable truths and resistance to populist ignorance.

The structural transformation of the public sphere through digital media also changes the way science is conducted and communicated. This raises fundamental questions of a practical nature concerning data protection, transparency, and the power of suggestion of digital algorithms, as well as philosophical questions about human self-understanding given the increasingly superior functional performance of artificial intelligence. A fair, inclusive, and humane management of the complex radical processes of change associated with digitization requires new spaces for discourse in the dialogue between scientific, social, entrepreneurial, and political practice. Only in this way can the complex expert knowledge be included without necessarily leading to an "expertocracy" that Stohschneider rightly rejects [26: 190]. Digitization offers numerous opportunities for innovation, without which accelerated adaptation to the challenges of Climate Change will hardly be possible. So far, however, the reflections and institutions that seek to ensure the responsible handling of digital opportunities are underdeveloped.

7 Paradigm Shift in the Understanding of Progress

The science system reflects information highly selectively in specific codes that reduce complexity and thus guarantee efficiency, effectiveness, and verifiability. This enables specialization and dynamization but at the price of a correspondingly limited perception [23: 88]. Secondary sequences alien to the subsystem are produced but usually not recognized as such, and therefore not adequately processed. In the sense of reflexive modernity [3], however, it will be important to think systemically about the social side effects of technical and socio-economic innovations from the outset. Therefore, the rapidly changing knowledge societies depend on a prospective responsibility of their scientific institutions. Ultimately, what is at stake is a "cultural revolution" [6: FN 3]:

> We are experiencing not only a time of change, but a real change of times [...] Ultimately, it is a matter of 'steering the model of global development in a [different] direction' and 'redefining progress:' 'The problem is that we do not yet have the culture we need to counter this crisis. It is necessary to form leadership that shows the way.' This considerable and urgent task requires, at the cultural level of academic education and scientific research, a generous and concerted effort to bring about a radial paradigm shift, and even more so–if I may say so–a 'courageous cultural revolution'.

This is a strong claim: the universities should contribute to a paradigm shift in the understanding of progress. The task outlined here reads like the Advisory Council on Global Change as a "big transformation" for a new social contract [31]. This is not only the postulate of some scientists but already a political decision: With the SDGs and the Paris Climate Treaty, the international community made a factual commitment to such a revolution. By addressing both the old and newly industrialized countries as well as the countries of the Global South, and by accepting the planetary boundaries as framework-giving guidelines, these documents pass the development concept that largely shaped the UN until now. However, this parting is still ongoing so that contradictions arise in the tension between ecological and socio-economic goals [9, 17]. How this affects the everyday life of politics, business, and society must be explained thoroughly as the associated potential for conflict is considerably underestimated and leveled out to harmonize the discourse.

The implementation of SDGs necessarily includes a change in the cultural patterns and guiding values of society. This change cannot be induced by a top-down decision. It usually occurs gradually from a complex interplay of changing values, the institutional design of framework conditions, and pioneers of transformative practice. Indispensable at all levels is the leadership addressed by Francis. Its core task is to point out the ways for a new understanding of progress.

The concept of resilience established itself as an interdisciplinary focal point for this debate [4]. In the future, progress will be measured by its support through nature [28]. Given the complexity and technical power of modern society, an unlimited or limitless expansion of action potential does not lead to optimized freedom. It rather has a corroding effect through arbitrariness and high-level control effort to maintain social and ecological security. Especially regarding modern technology, freedom needs an "intelligent self-limitation" to protect its preconditions and cultural embedding contexts. It holds unlimited possibilities but the danger of manipulation at the same time. Given the rapid development and multi-layered ambivalence of digitization, this Janus-faced nature of possibilities currently gains novel attention. Without cadence between the moral integrity of actors, legal control as well as cultural competences for interpreting and handling the associated processes of change, technical progress can become "backward-looking." Positively phrased, this process requires strong moral, cultural, and legal competence to have a beneficial effect. The decisive program of this progress for the future is not a further expansion of power over nature, but rather the recovery of power over power through ethical–political control of the use of natural resources under strict observance of human rights and the principles of sustainable development.

8 Hope Beyond Optimism

Christians are rightly expected to deliver a message of hope: "the gospel, good news." This almost contradicts a sober view of the present situation of the world in which eco-social catastrophes become increasingly likely. In the public debate, this tension is mainly resolved by playing down the perception of the situation. In the USA, for example, some branches of the Christian churches side with those who prevent transformation instead of siding with those driving it. Besides, the theological underpinning of discourses of fear combined with rhetoric of eco-apocalypse is bad theology. It depends on differentiation: Christian hope is not optimism but "thwarted hope," a hope that knows about human failure and the calamity of suffering and guilt. It does not draw its confidence from a cheap optimism but from the certainty that God accompanies people also in the abysses of existence. It knows that processes of transformation are often painful and full of uncertainty but that they usually also hold unexpected opportunities.

A theology that encourages decampment and confidence in the Great Transformation needs to revise the concept of progress: toward one that does not rely on a promise of "faster, higher, further" but on resilience and successful life through solidarity of people and fellow creatures. Humility, the ability to resonate, solidarity, and creativity are guiding virtues of a civilization that is breaking up the growth model that has become a metaphysical substitute. A turning away from the "drug" of growth, neither resigned nor frozen in static models, is the social and economic-ethical core of a Christian alternative to the current project of expansive modernity.

The religious distinction between immanence and transcendence can enable sober confidence that critically sees through ideological promises of meaning and knows about the finiteness of all human efforts. It rejects both naive utopias and linear ideas of progress as well as resigned dystopias and fears. She is critical of some contemporary natural-religious movements in which the need for recognition of a higher power has shifted entirely toward nature. These are then often no longer communicable with the possibilities of action and forms of the rationality of modern technology.

At the core of Enlightenment 2.0 lies the concept of freedom and responsibility. It constantly seeks a new balance between conservative preservation and proactive shaping of an open future. Such a new phase of the Enlightenment complements the expansive turn of reason outward, which shaped the Modern Age, with an inward turn of reason. For the power over nature is only a value in freedom, if combined with the power of man over himself.

9 Conclusions

Currently, our expansive modernity steers toward an ecological suicide that can only be halted by a new phase of enlightenment. At its core lies an integral allocation of knowledge and responsibility. It overcomes the dominating positivist division between knowledge and values. It understands both ethical questions and social transformation as integral components of scientific research.

This chapter assumes that the challenges of climate change and the environmental crisis in the Anthropocene radically question the normative foundations of the current social model. Key concepts of modernity such as progress and prosperity, reason and humanity, freedom and justice must all be spelled out anew to retain or regain their beacon function. The title "Enlightenment 2.0" summarizes all these claims, and aims to record the normative and socio-theoretical achievements of the first Enlightenment by developing them critically with respect to their ecological and cultural preconditions. The transition from expansive modernity—whose maxim was the expansion of power over nature—to a regaining of responsible control and taming of power is of decisive importance. For society, this requires an intelligent self-limitation as well as a reorientation of innovation dynamic geared towards sustainability and resilience. It is a program for ecological modernization, with a special focus on the role of science, the understanding of rationality, and the transformation of our human relationship with nature.

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Enlightenment 2.0? What We Would Have to Change if We Wanted to Stay

Jörg Wernecke

Abstract We have entered a "new age" which, sometimes labelled Anthropocene, not only represents an increase in anthropocentrism in the form of transhumanism and human (genetic) enhancement but also confronts the "anthropos" with global existential threats in the form of climate change, limited resources, damage to the biosphere, destruction of ecosystems and as a result of our own habitat, growing social inequalities, migration, political destabilizations etc. All of this takes place without the possibility of retreating to refuge castles that can be sealed off locally because climate change as a global phenomenon affects everything and everyone in every place. The decline in biodiversity and the further increase in geosocial pauperism (including environmental *in*justice) are "merely" different sides of the same coin.

Keywords Ecological disruption · Future of enlightenment · Responsible innovation · Global political governance

1 Introduction

We have entered a "new age" which, sometimes labelled Anthropocene,[1] not only represents an increase in anthropocentrism in the form of transhumanism and human (genetic) enhancement but also confronts the "anthropos" with global existential threats in the form of climate change, limited resources, damage to the biosphere,

[1] "Considering these and many other major and still growing impacts of human activities on Earth and atmosphere, and at all, including global, scales, it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term "Anthropocene" for the current geological epoch." Cf: Crutzen and Stoermer [4: 17]; In extenso, e.g.: Harari [10: 101–140].

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destruction of ecosystems and as a result of our own habitat, growing social inequalities, migration, political destabilizations etc. All of this takes place without the possibility of retreating to refuge castles that can be sealed off locally because climate change as a global phenomenon affects everything and everyone in every place. The decline in biodiversity and the further increase in geosocial pauperism (including environmental *in*justice) are "merely" different sides of the same coin. In view of this present situation, Latour's [17] thesis has great persuasive power: "The hypothesis is that we can understand nothing about the politics of the last 50 years if we do not take the question of Climate Change and its denial front and centre. Without the idea that we have entered into a New Climate Regime, we cannot understand the explosion of inequalities, the scope of deregulation, the critique of globalization, or, more importantly, the panicky desire to return to the old protections of the nation-state—a desire, that is identified, quite inaccurately, with the 'rise of populism'" [17: 10].

Latour's [17] current diagnoses coincide in many aspects with Weizsäcker's and Wijkman's analyses of a full world confronted with limited resources, the increasingly global destruction of ecological and human habitats, and their negative social and political consequences. Their analyses lead them to the conclusion that we need "[…] a different political and civilizational philosophy for our area of the *full world*" (2018: 93). In the face of unresolved global existential challenges, they conclude that we are living in an age of "philosophical crisis" (ibid: 58, 91). They summarize their task as follows: "Beyond the task of intellectual understanding, philosophical analysis should help clarify where the potential partners stand in terms of a transition to values and mindsets for true sustainability on Spaceship Earth" (ibid: 58). In more differentiated terms, their aim is the global establishment of a strong sustainability (ecological, economic and social (including intergenerational justice)) based on a specific normative foundation ("values and ways of thinking" (see above)). This implies the insight that science, technology, economics and politics, in addition to their empirical-descriptive and operative competencies, require a normative orientation and ethical foundation in order to cope with global ecological challenges.

Weizsäcker's and Wijkman's assumption of a philosophical crisis provokes an alternative thesis: It is by no means a philosophical crisis but a concrete practical fiasco of the political economy, of national and international politics, of the world community (global governance). Indeed, there is no lack of problem identification and analysis, but we are regrettably bad at the implementation of solution strategies as von Weizsäcker and Wijkman [31] state. It is by no means a philosophical crisis in view of the existence of elaborated philosophical diagnoses of environmental ethics[2] and economic ethics, as well as philosophical, economic, scientific-technological

[2] Since the publication of "Silent Spring" in 1962, a differentiated discourse landscape on bioethics and environmental ethics has developed, ranging from ecology and climate change, sustainability concepts and climate policy to genetic engineering and Earth engineering. A wide variety of discourses can be identified at both national and international level. In the German-speaking scientific communities, in addition to the classics such as A. Schweitzer, H. Jonas and others, authors such as Birnbacher et al., who have developed elaborate concepts of ecological ethics, should also be mentioned with regard to ecology. A current overview can be found here: Ott et al. [21], Heidbrink et al. [11].

and political problem-solving strategies seeing the ecological, economic and political challenges of the present. There is also no lack of scientific-empirical research results and economic models that prove the necessity of changing human practice in the face of increasingly destructive interventions in the Earth's ecosystem.[3] Furthermore, there is no shortage of alternative technological and economic models of action in the technical and economic sciences[4] that offer a more appropriate approach to global ecological challenges.

2 Sustainable Enlightenment?

In view of (better: despite?) all these philosophical and epistemic discussions, the ecologically engaged citizen wonders why it should not be possible to avert the predicted worldwide disaster which will soon affect many regions so that only an elite minority will be able to survive in habitable areas? Is it the limitation of knowledge and concepts only, and do we need a new Enlightenment 2.0, as demanded by von Weizsäcker and Wijkman [31]? Alternatively, are the current negative messages "merely" a (cultural) pessimism or modern variants of apocalyptic visions à la Hieronymus Bosch, which, after all, are sure to attract a great amount of media attention? At least the current state of scientific knowledge—e.g. based on the IPCC Report 2018—excludes trivializing interpretations; despite all attempts of a disinformation policy, e.g. by the US administration of Trump in the sense of the denial of a largely man-made climate change.

In view of this situation, one cannot help but remember Kant's diagnosis of his times:

> When we ask, Are we now living in an enlightened age? the answer is, No, but we live in an age of enlightenment [14, 15: 59, A 491].

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[3] Despite all the prophecies of doom: The strategies at national and EU level are certainly worthy of note (e.g. Germany's sustainability strategy, the phasing out of nuclear energy and the long-term transformation of the energy industry from fossil to sustainable energy sources), although they are not sufficient. The conversion of traditional industries has only just begun. Lively activities can also be identified on an international-global scale, the best-known examples being the following: UN Climate Conferences (Kyoto, Paris, Kopenhagen, Katowice), [13]. Actual: UN Climate Change summit 2019 the "year of transformative solutions" and "avoid the disastrous effects of Climate Change". Or: The United Nations World Water Development Report 2019. Leaving no one behind. See also: UNESCO [29], Or: Convention on Biological Diversity (2014).

[4] Since Homann and Ulrich, business ethics in the German-speaking scientific community has been characterized by a variety of differentiations in discourses ranging from individual, corporate and institutional ethics to concepts of global economic action, such as concepts of governance ethics, cultural business ethics (Beschorner), republican business ethics (Steinmann; Löhr), analyses of the political role of global companies (Scherer, Palazzo, Butz), or micro- and macro-analytical studies on the limits of the market economy, etc. In particular, the economic concepts discussed by von Weizsäcker and Wijkman [31: 101–148] are impressive examples of already existing alternatives to multidimensional problem-solving strategies of economic action.

This then raises the question: What further measures are needed to establish an enlightened age today? Because we are scientifically quite "enlightened" about the causes and consequences of our current global ecological challenges, an additional question arises: Is "only" the consistent implementation of our knowledge missing or what could be meant beyond that when von Weizsäcker's and Wijkman's [31: 93] demand an "Enlightenment 2.0" that is not a mere fashion?

More modestly, one could first ask about the "future of the Enlightenment" itself [22]. And this is not only an academic and ecological question but a political issue, which Kant already stated in "Perpetual Peace" (1795). In view of the current geopolitical developments, for example in the international scenery of the USA, Russia or the People's Republic of China, there is an increase in regional military conflicts on the background of geopolitical interests of third parties. Looking at the present geopolitical situation the question might arise: before establishing Enlightenment 2.0, should it perhaps be more important, relevant to first secure the achievements of Enlightenment 1.0 and to establish them globally? Some contemporaries may criticize the plea for Enlightenment 1.0 as a new kind of Western cultural chauvinism and new cultural imperialism. But, in the following, the plea for an Enlightenment will be classified as a result of painfully elaborated (European) insights in view of manifold cultural, political and human catastrophes (e.g. serfdom, Thirty Years' War, global imperialism or the political totalitarianism of the twentieth century and the Holocaust), the catastrophes which can also be identified in present times. We are still in the tradition of the European Enlightenment and—in view of its achievements—this is a good "narration":

- Normative in terms of lifeform ("Lebensform"): For example, ideas of the universality of human rights, social justice, rule of law and sovereignty of the people (democracy);
- Normative in terms of epistemology: Science as research, methodical-rational foundation, reproducibility, validation within a scientific community, science and technology must serve society (progress of knowledge = social progress) etc.

The possible negative *dialectic inherent* in the Enlightenment should not be ignored, however, since this reference can also serve to prevent the danger of developing totalitarian rationalism [e.g. exclusion of the other, complete rationalization of the lifeworld(s), technocratic euphoria of progress (technocracy 4.0 in view of the complete digitalization of the lifeworld(s))], ecological totalitarianism or ecological paternalism. The authors von Weizsäcker and Wijkman [31] certainly share this dialectical view of the Enlightenment. They, therefore, want to establish an alternative concept of Enlightenment that avoids the old mistakes[5] as far as possible.

Back to the question: Do we need a new Enlightenment, an Enlightenment 2.0? In the sense of differentiation of this question, a thought by the author of [8]/1990

[5] This includes, for example, the following: dogmatism of a strict rationalism [31: 93], general reductionisms ("philosophical errors" (ibid: 83), doctrinal interpretation of culturally and temporally conditioned economic models (misinterpretations regarding Smith and Ricardo, Darwinism; ibid: 75–83), analytical-reductionist approaches within the life sciences (ibid: 84–88).

could possibly contribute to the (enlightenment) clarification. First of all, it is a classic philosophical topos when Foucault is using the term *ethos* of philosophy (alternatively, anti-Kant directed), which tries to project Kant's demand for maturity ("Mündigkeit") in his own perspective into the present:

> I shall thus characterize the philosophical ethos appropriate to the critical ontology of ourselves as a historico-practical test of the limits that we may go beyond, and thus as work carried out by ourselves upon ourselves as free beings.[6]

In my opinion, however, Foucault's epistemologically justified method in the form of genealogical-archaeological enlightenment with regard to the "merely" traditional, power-legitimized forms of rationality, ethics and anthropology is insufficient in that it is normatively underdetermined, ultimately subject to a contingency or arbitrariness of the aesthetics of the personal life plan (a form of life) (1990: 49). Even if it is by no means considered possible to derive irrefutable truths or absolute normative-ethical certainties from the (alleged) certainty of metaphysics one issue is evident: in view of the global existential dangers of the ecosystem Earth and the human habitat, the "mere" design of a form of life in the sense of its aesthetics experiences is insufficient to the extent that an ontologically absolute limit is existing. Because of von Weizsäcker's and Wijkman's [31] analyses, the current "climate regime" identified by Latour, the prognosticated ecologically negative effects, and in view of the empirical research results, Foucault's philosophical ethos needs a reformulation, an inversion:

> It is the philosophical ethos that the (critical) ontology of ourselves is peculiar, as a practical test of the limits that we CANNOT cross, and where we experience in ourselves the BORDERS as free beings.

The plea for an Enlightenment 1.0 supported in this paper, however, is not to be misunderstood as the reanimation of transcendental metaphysics (Kant) or of the (immanently contradictory) epoch called "Enlightenment", but is to be classified as a pragmatic-empirical argument, which is *pragmatic-transcendental.*[7] Ontological limitations, empiricism (Gaia; cf. [18]) itself refers us to the *conditions of the possibility of our action*, i.e. to the limits of our human existence, which builds on the "mundane order", i.e. on the habitability of planet Earth and on a (relatively) stable biosphere. Thus being aware of these limits is not a pathological symptom of an anxiety neurosis or mental catastrophe cinema, but an expression of practical wisdom (called "phronesis" by Aristotle). And, despite all (relativistic) multicultural discourses on—largely unrealistic—universal ethics, the ecological global challenges necessitate a reason-guided understanding that *a universal (minimal) ethos has to be established globally* (ἔϑος, **e**thos). The "Earth Charter", finally formulated in 2000 and inspired by the UN, ultimately pursues an analogous intention at the

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[6] Foucault [8: 32–50].

[7] In the sense of a (ontological) "condition of possibility" and not in the discursive-communicative meaning at K. O. Apel or J. Habermas.

treaty-theoretical level, which, however, has failed general recognition under international law [28]. Both von Weizsäcker's and Wijkman's [31] demand for values and an Enlightenment 2.0 appropriate for the current situation and Latour's plea for a reorientation toward the terrestrial (instead of the local and the global) (2018: 94)[8] could possibly be focused on the question of the **ä**thos (ἦϑος): the (still possible (residential)) place that is both concretely habitable and normatively ethical constituted (et vice versa). This borrowing of an Aristotelian topos, the dependency of **ä**thos and **e**thos, is intended to "only" recall the reciprocal dependency between the "lifeworld" ("Lebenswelt", place of living) and normative-ethical conditions, a relation that has a global explosive force in view of the ecological challenges of the present. From an economic, technological as well as political perspective, there is a need for a revision of humane practice to date, which in particular also requires an ethical foundation with a global orientation, if places shall be preserved that can still be inhabited in the future not only by some but by *all* people. The extensive discussions on environmental ethics and bioethics in the last 50 years bear eloquent witness to these efforts. The analyses and insights of ecological, economic and technological "ethics of responsibility" (Verantwortungsethik) as well as their risk-ethical extensions demonstrate the complexity of the challenges (e.g. the problem of many hands, distributive justice of risks etc.) and illustrate the limitations of individual, group-centred, institutional and political entities, who are made responsible for a mandatory *global* ecological extension of international law whose ratification continues to fail.[9]

First insight: We need new enlightenment about the ontological conditions that limit the possibilities of human practice.

3 Enlightened Responsible Innovation?

Before briefly outlining the underlying question of a possibly adequate global governance at a later stage, a philosophical problem of technology should first be addressed. There are quite a few voices that identify the cause of the destructive ecological consequences of the present especially in the Enlightenment itself (in the sense of a one-sided orientation toward rationality, technology and science (disenchantment of the world)). If, however, a fundamentalist critique of technology and science—thought through to the end—ends in a suicidal vacuum of action ("anthropos" has only survived evolutionarily as an instrumental-technical primacy and has defined

[8] "The Global and the Local alike afford us an inadequate purchase on Terrestrial, which explains the current hopelessness; what can be done about problems at once so large and so small? A discouraging prospect, indeed." His answer, which may disappoint at first, is, in my opinion, appropriate, to describe a critical inventory of previous models / strategies and their appropriateness in view of the current situation (ibid.).

[9] At the 1992 United Nations Conference on Environment and Development in Rio de Janeiro (UNCED), for example, no agreement was reached on anchoring the Earth Charter in international law, inspired by the Brundtland Report, and a non-binding declaration (Rio Declaration) was adopted.

himself accordingly (up to the distortion of himself as in current transhumanism)), while the technology euphoria [12: 56ff] that has dominated until the beginning of the last century (due to its ignorance with regard to ecological side effects) represents the other prohibited zone of human practice in the face of the terrestrial challenges of the present and future, if both these stances, technology pessimism and technology euphoria, do not represent meaningful alternatives for practice in the sense of the survival of homo sapiens, could a “better technology” help in this situation? The question of a more appropriate technological response to the current ecological challenges can be elaborated at several levels in the sense of *responsible innovation.* It is important to note the Technology Assessment (TA) models developed in the 1990s, whose primarily functional-descriptive analyses with regard to the consequences and side effects of technological implementations have increasingly been supplemented by normative criteria. We have to learn only the consistent application of an ethical-normative TA will be able to meet the complex challenges of potentially negative consequences of technology applications, e.g. implementing the precautionary principle as well as classifications and assessments guided by an ethics of risk (e.g. normative definition of damage, distributive justice and reasonability of risks, consideration of benefits and risks of damage, etc.).[10] Certainly welcomed would be the insight that technology development has to be accompanied a priori by normative ethics instead of “repairing” [9: 9–31] possible negative consequences and side effects a posteriori socially normatively (e.g. adjusting law) or ethically (e.g. take intergenerational justice into account). However, TA practice still needs to be supplemented to the extent that ecological ethics of responsibility must be included and implemented, for example in the perspective of an ecological precautionary principle (not only a TA in the sense of damage prevention but also—for example—a complex environmental impact assessment[11] and sustainability assessment).

If technology design in the sense of “responsible innovation” wants to be more than “mere” procurement of acceptance or lobby-centred industrial policy or a strategy to avoid expensive repair costs, then it must also critically address the question of its own normative understanding of innovation and progress [30]. This problem is directly linked to the topic of the Enlightenment. The original Enlightenment

[10] The 1992 Declaration in Rio de Janeiro defined the precautionary principle: “Principle 15: To protect the environment, States shall apply the precautionary principle generally within the limits of their capabilities. If serious or permanent damage is imminent, a lack of complete scientific certainty must not be a reason for postponing cost-effective measures to prevent environmental degradation”; cf: https://www.un.org/Depts/german/conf/agenda21/rio.pdf). For an ethics of risk: Nida-Rümelin [20: 862–885], Woopen and Mertz [36], Weber [34].

[11] For example, a list of criteria in the German Law on Environmental Impact Assessment (UVPG) reads as follows: “Protected goods within the meaning of this law are: (1) human beings, in particular human health, (2) animals, plants and biological diversity, (3) land, soil, water, air, climate and landscape, (4) cultural heritage and other material goods and (5) the interaction between the aforementioned objects of protection”. (UVPG, Teil 1, §1(1)) http://www.gesetze-im-internet.de/uvpg/BJNR102050990.html#BJNR102050990BJNG000104310; translation by the author).

of the eighteenth century[12] was always associated with the idea that the progress of interacting economy and technology will contribute to the progress of society and politics. This historical period was not merely an anthropological or cultural project to enhance the status of man as a moral person [19], but also a scientific and technological innovation program. Science and technology were expected to improve individual and social (living) conditions. Diderot and d'Alembert thus intended with their Encyclopédie to convey and enlighten the entire body of knowledge known in the eighteenth century, including the production processes, the technical and scientific know-how, as detailed impressively by many elaborate copper engravings.[13] The Encyclopaedists of the Enlightenment also very much approved of the influential verdict by Francis Bacon at the beginning of the seventeenth century that science must always serve society in the form of its technologies and that nature must be defeated [2].[14] This science program can simply be summarized as follows: (political and social) progress by (scientific-technological) innovation. This "marketing slogan" of Enlightenment 1.0 has lost its unrestricted power of persuasion since the end of the last century due to the many ecologically destructive side effects, while the manifold merits of the innovation program have not been denied. Progress and innovation are no longer synonyms that can be taken for granted. On the other hand, both concepts require *normative reformulation*: progress and innovation with regard to which goals, criteria and (re-)evaluations?

Second insight: We have to implement an (ethically) enlightened principle of "responsible innovation", which must critically address the question of the normative (ethical) understanding of innovation and progress.

This postulation of a normative reformulation of progress and innovation includes a plea for a liberal, democratically constituted community reflecting an experimental, learning-oriented perspective on technical sciences as well as philosophical ethics. The interdependence of a democratic constitution and problem-solving-oriented scientific research can be illustrated with reference to the pragmatist John Dewey. First of all, "A democracy is more than a form of government; it is primarily a mode of associated living, of conjoint communicated experience" [5: 128].

According to Dewey, democracy enables not only free communication but also the equal exchange of interests as a result of the constant transformation of social

[12] Historically, the plural would have to be chosen more appropriately: the Enlightenment was quite different in France (e.g. Diderot, Voltaire, d'Alembert), Scotland (e.g. Hume, Shaftesbury), Germany (e.g. Kant, Wieland, Herder, Lessing) and Italy (e.g. Gravina, Muratori, Vico).

[13] The complete title documents this claim: "Encyclopédie ou Dictionnaire raisonné des sciences, des arts et des métiers" published 1751–1780.

[14] According to Bacon (1561–1626), man possesses on the one hand an ability to shape his environment, nature, and ability (power, "potential"), which on the other hand is to be used to produce ("generare") new knowledge as a result of works. In the sense of the physical subjugation of nature, he formulates that "[…] through works to conquer [to; addition of the author] nature itself […]" [2: 77]. He becomes even clearer at the end of the Novum Organum (1620) when he states, with regard to the advantages of his method that "[…] an improvement of human relations and the extension of his power (potestas) over nature follow from it" (ibid: 611). Translation by the author.

behaviour, the permanent readjustment to new situations arising from manifold interactions (ibid: 117f, 120). She enables participation in various intellectual challenges, as a result of the development of new tasks and an appeal for creative thinking. Democracy is an experimental, learning-oriented form of life, so only a liberal-democratic society can provide the preconditions for (potentially) successful problem solving understood as constantly new adaptations to dynamically changing environmental conditions. The democratic form of life shares its experimental, learning-oriented character with the modern natural sciences, which Dewey repeatedly accentuates positively, especially with regard to their instrumental, i.e. problem-solving character by empirical research. Bringing both together this means: Only a liberal-democratic society enables freethinking, the development of free creative intellect and, as a result, creative research in order to realize a social development for the better (Dewey's "meliorism") using technology and science. For Dewey, democracy is, therefore, the ideal institutional condition for the kind of philosophy which he demands of civilization, including boldness for "[…] a free imagination of intellectual possibilities […]" [7: 11] by developing new creative ideas, drafts, imaginations, problem solutions regarding humane future and its challenges.

Not only democracy and science but also ethics and moral philosophy is characterized by Dewey in the sense of an experimental, learning-oriented insight, in the sense of a problem-solving-centred learning process with regard to social challenges and conflicts. On the one hand, he, therefore, pleads for the application of the scientific method within ethics; on the other hand, science and technology also experience normative social and ethical questioning. In Dewey's sense, this does not mean a levelling of science and morality. On the other hand, however, science, technology and ethics can no longer proclaim an independent status; rather, science and ethics with regard to their objectives refer to the same normative orientation in the form of a successful humane, social life practice [6: 173].

This means: the future challenges can only be solved by an understanding of science in which ethical-normative perspectives are a priori integrated. "In spite, then, of all the record of the past, the great scientific revolution is still to come. It will ensure when men collectively and co-operatively organize their knowledge for application to achieve and make secure social values; […]" [7: 329]. This applies equally to pedagogy (education), gearing to the development of individual creativity in the sense of problem-solving competence and practice in a normative way of life, i.e. a democratic form of life as an expression of socially shared interests and goals (cf [5: 94–116,117–129].

Third insight: The postulation of (ethically) normative reformulation of progress and innovation includes:

(a) an understanding of science and innovation in which ethical-normative perspectives (as developed by Dewey, Adorno, Walzer) are integrated a priori;

(b) the plea for implementing liberal democratically constituted communities;

(c) the call for a global public space of democratic discourse to develop and implement political solution strategies globally.

Following Dewey, this understanding applies to the ethical approach that has been called for. Ethics needs to be interpreted in the sense of a problem-solving strategy, which is experimental learning. This means ethics as adaptation of our habits to dynamically changing lifeworld(s) by new processes, designs of (empirical experimental) ethics in the face of the inadequacy of actual normative orientation possibilities, of a concrete conflict, lack, and not in the sense of metaphysically absolute certainties in the form of the realization of a good in itself. Formulated with Adorno:

> We may not know what is absolutely good, what is the absolute norm, indeed we even do not know only what is man or the human and humanity, *but what is the inhuman, we know very well.* ([1: 261]; translation by the author).

Both Adorno's and Dewey's positions can be completed with reference to Michael Walzer. According to Walzer's understanding, morality and ethics need neither to be discovered nor invented. Rather we already are living in a community marked by moral commandments and prohibitions, in which new moral adaptations, i.e. interpretations, always must be made to the existing moral norms depending on the new situation and/or social conflicts. The resulting plurality of moral cultures based on specific interpretations, however, does not mean the acknowledgement of a general cultural relativistic ethics. Following Walzer, our moral norms emerge from a historical- evolutionary process of interpretation of *universal* prohibitions, which are anchored *naturalistically* in a "[…] kind of minimal and universal moral code […]" [32: 24]. In addition: "There is a minimal morality, a 'thin' catalogue of justice, whose mainly negative character is probably due to people's common vulnerabilities and fears. Does this morality have a foundation? If so, then I'm pretty sure it's a naturalistic foundation" ([33: IV]; translation by the author).

In view of the current threat to the human (physical and moral) fundaments and the social-political threats to be expected in the near future, in view of our knowledge of the inhuman, *it is time to act*. In view of the global challenges in ecology, which by far exceed the traditionally known inter-individual and social conflicts, the already existing analyses and knowledge of ecological, economic ethics and technological ethics of responsibility (as well as their risk-ethical extensions) prove concrete problem-solving strategies. Accepting these analyses without practising sustainable problem-solving strategies there is an apocalyptic vision: In the near future, in view of current dynamic environmental changes, we will be confronted with the extent of hitherto unknown global humanitarian catastrophes (e.g. global migration movements). It is time to act: *globally.*

4 Looking Back and Looking Forward

"When we ask, Are we now living in an enlightened age? the answer is, No, but we live in an age of enlightenment" [14, 15: 59, A491]. Indeed, we are good at problem identification and analysis, but regrettably bad at the concrete implementation of solution strategies. The question should also be repeated: What further measures are needed to establish an enlightened age today?

Even if, with regard to the diagnosed deficiencies, fatalism sometimes seems to prevail overconfidence, the task remains: Enlightenment means creating a public space (even according to the classical view), must be understood with regard to both the global scope of the negative consequences of current human actions and the positive achievements of our technological innovations under the necessity of public political measures, discussions by deliberation and democratic participation. Identifying the relevant knowledge in this respect requires public transparency and a public space for discourse. The reference to a public space intends to draw attention to this: Enlightenment has always been political! This view suggests the conclusion that the currently demanded Enlightenment 2.0 must act politically globally. The manifold activities of the UN, UNESCO, and others with regard to climate and species protection document emphatically this insight. In its global efforts of enlightenment, they are using on a classic model of political philosophy, i.e. the *contract theory* based on consensual procedures.

Unfortunately, these meritorious activities also reveal their greatest weakness, i.e. the non-binding nature of a contract theory in the absence of binding law in a global perspective. Neither can the available legal framework in the form of international law formally provide the required binding force nor can an environmental law (however, praiseworthy it may be) that does not reach beyond the borders of a single state cover the inherent dynamics of complex systems—the unpredictability of global consequences of initially local interventions with regard to the global biosphere. In view of the interdependence of local activities and their global effects, the requirement under international law that states should not interfere with each other is ecologically and legally obsolete. Accordingly, it can be concluded that neither the polluter pays nor that legal structures are available that define violations bindingly and punish them under criminal law. The deficiencies are even more serious from a responsible-ethical perspective: The precautionary principle, which has long been propagated, must also be helped to achieve a global breakthrough of the principle of sustainability based on an ethics of responsibility [25]. The fact that questions of distributive justice of resources and opportunities among others, with regard to non-industrial nations, urgently require a political and economic response in the sense of global governance (Copernicus Institute; Biermann et al. [3]), and that the developed industrial nations and globally operating companies have a special responsibility, are truly no new insights. The global fight against malnutrition caused by poverty, for example, is not only due to the ideas of universal human rights but also improves local ecological practices leading to a reduction in global environmental damage.

However, there is still no answer to von Weizsäcker's and Wijkman's [31] question: What other political and civilizing philosophy do we need? The question aims at the future in present times and the attempt of an answer is only possible in the scope of visionary thinking, in the scheme of a *political utopia*. Even before all "Realpolitik" (political governance), the question arises of a necessary change in the understanding of the political matter itself. While in the nineteenth-century politics first defined itself locally (settlement space), territorially (dominion), religiously, genetically dynastically or in the sense of popular and later national sovereignty with regard to the claims to power and domination, in view of the current global challenges *politics must constitute a new global understanding of itself*. The phenomenon of the political itself needs reformulation with a view to the terrestrial, the global. This challenge affects both constitutional law and international law. In view of the global ecological challenges, we need a *terrestrial understanding of politics* that is no longer primarily local or dominated by national interests but global in the sense of a new definition about autonomous political sovereignty with a general globally idea. This perspective is a utopian view of the current prevailing "Realpolitik", but Kant's essay "Perpetual Peace", which can certainly be regarded as a precursor of current international law, also had a "merely" visionary character. And: the "*world civil law"* (1795/96: 203; 213)[15] (which has to be reformulated for the twenty-first century) possesses a real explosive force, especially today, in view of the interventions in the biosphere caused by human activities that destroy our habitats, fundamental human rights to habitat, cultural self-determination, etc.

An analogous change of perspective is also necessary with regard to economic action or the scientific economy: the economy must define and constitute itself globally, both theoretically and practically, and no longer primarily in the sense of national grounded economies. The politically influential economic models of the present are still shaped by their (nation-stated) economics or ideological ancestors and are currently experiencing a revival globally. This change of perspective in the sense of entanglement of the local and the global, illustrated by Weizsäcker and Wijkman through, e.g., models of a circular economy and blue economy [31: 140, 113], have to be a goal and result of political ratification and implementation, as well as an orientation towards a *terrestrial world citizenship law*, that supplements the UN Declaration on Human Rights.

The reference establishing a *terrestrial world citizenship law* can already be classified as an element with regard to the *civilizing turnaround*—called for by von Weizsäcker and Wijkman [31]—or a new civilizing philosophy to be formed. This certainly includes a readjustment of the interpretation of the relationship between nature and culture. In the nineteenth century, a Eurocentric civilization formed by science and technology, which defined its access to nature by means of its scientific-technological understanding of culture (and vice versa), has established itself globally. Even if a metaphysical or ontological understanding of nature in the sense of a nature-in-itself ("physis") or ontological definition of nature can no longer be supported, a recollection of human naturalness, i.e. corporality, can function as a regulative of technological fantasies of omnipotence—despite all manifestations of actual discussions of transhumanism. It is an empirical fact: we are a species that primarily depends on a (relatively) stable biosphere called "nature". In view

[15] Kant restricts this ius cosmopoliticum to a visitation right (ibid: 214). The UN "Declaration of Ethical Principles in Relation to Climate Change" (2017) lists further rights and obligations of states, e.g.: "Denial of acts contrary to human rights, fundamental freedoms, human dignity, and concern for life on Earth; Prevention of Harm; Precautionary Approach; Equity and Justice; Sustainable Development; Solidarity; Scientific Knowledge and Integrity in Decision-Making; Responsibility, […]" (https://unesdoc.unesco.org/ark:/48223/pf0000260129).

of the current outstanding scientific-technological possibilities and solutions, we need a new global culture of "hexis" (ἕξις, habit), a globally internalized "habitus", which has to be characterized by the imperatives of wisdom, prudence, great caution and responsibility with regard to interventions in complex phenomena such as the biosphere (environment, climate, etc.).

Fourth insight: we need:

(a) An alternative political and civilizing philosophyby visionary thinking of a political utopia(e.g. terrestrial world citizenship law),

(b) A new global culture of "hexis" (habit), an internalized "habitus" of all mankind, which has to be characterized by the imperatives of wisdom, "phronesis" (practical virtue) by prudence, and responsibility.

In summary of the analyses of the current global political and ecological situation, a further déjà-vu with Kant is almost inevitable with regard to the challenges of civilization:

> We are at this time in a high degree of culture as to arts and sciences. We are civilized to superfluity in what regards the graces and decorums of life. But to entitle us to consider ourselves moralized much is still wanting. Yet the idea of morality belongs even to that of culture; but the use of this idea, as it comes forward in mere civilisation, is restrained to its influence on manners, as seen in the principle of honour, in respectability of deportment, &c. Nothing indeed of a true moral influence can be expected so long as states direct all their energies to idle plans of aggrandizement by force, and thus incessantly check the slow motions by which the intellect of the species is unfolding and forming itself, to say nothing of their shrinking from all positive aid to those motions. But all good that is not engrafted upon moral good is mere show and hollow speciousness - the dust and ashes of mortality. And in this delusive condition will the human race linger, until it shall have toiled upwards in the way I have mentioned from its present chaotic abyss of political relations. [14, 15: 44, A304/404].

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The Fridays for Future Phenomenon

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Abstract The “Fridays for Future” movement is a result of the increasing mistrust from young people in the political leadership of their respective countries. They are concerned that environmental topics, especially climate change are not addressed with the given urgency and protest for sustainable politics that consider public rather than private interests as a basis for decision-making. Sparked by the protest of one individual, its successful resonance among young adults and adolescents worldwide was triggered (and is still nourished) by increasing numbers of natural disasters. It flourishes due to the support by the technical possibilities of the internet, social media, and globalization. This contribution draws up a few numbers and facts supporting a fair assessment of the movement despite public bias.

Keywords Fridays for Future · Climate change · Public awareness · Challenges · Achievements

1 Development of the Movement

In 2018, a civil movement appeared that questioned human behavior concerning the climate of our home planet, the Earth. A movement has already become emblematic of the challenges of the twenty-first century. Schoolchildren around the globe started protesting for their future! They wanted to raise awareness for the progressing climate change, which they identified as a threat to life on this planet. The purpose of the movement was—and still is—to pressure politicians into finally acting against the anthropogenic pollution of the atmosphere that causes a continuous increase in Earth temperature, thereby leading to a cascade of related problems.

A Swedish teenager, then aged 15, inspired the movement—Greta Thunberg. On August 20, 2018, she sat down in front of the Swedish parliament with a cardboard

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sign saying: “Skolstrejk för klimatet,” or in English: “School Strike for Climate.” She demanded from her government to align the national carbon emissions with the international Paris Agreement it had ratified in 2016, but until then not implemented satisfactorily. Therefore, she announced that she intended to continue the protest for her future until the Swedish general election on September 9, the same year [2]. Her peaceful sit-in seems unique for the twenty-first century. However, it must be seen in continuity with forms of protest of the mid-twentieth century environmental and civil rights movement, especially Earth Day, which began raising awareness for similar problems and concerns in 1970 and brought to life the “first green generation”.

One day before the elections, she announced to continue her protest every Friday during school hours, until the Swedish politicians would finally take reasonable action to achieve the goals of the Paris Agreement. From that point onwards, protests inspired by her role model emerged all around the world. In the wake of the United Nations Climate Change Conference held December 2–15, 2018 in Katowice, Poland, the movement gained more and more public attention. As a result, an increasing number of international political leaders began to take the protesters and their urgent requests seriously. The same month, young people in over 270 cities around the globe began to coordinate school strikes held every Friday [1]. On January 18, 2019, for example, an estimated number of 45,000 students protested in Switzerland and Germany alone [7].

In retrospect, this date marks the beginning of an organized Fridays for Future movement in Germany. Here, several regional groups developed, resulting in a nation-wide organization starting to prosper. The activists are managing themselves through local WhatsApp chats, sharing their political and environmental opinions while recruiting like-minded people to join the strikes. In a weekly countrywide phone conference, group leaders connect to discuss strategies and future activities. An official webpage offers support wherever necessary. It also provides breaking news, unitary goals, or political statements, and it helps with recruiting new stakeholders. Eventually, these efforts led to the first mass protest on March 15, 2019. Their discontent and impatience with (political) decision-makers are understandable. Not only would possible effects of continued non-action impact heavily on their (and their children’s) lives. On top of that, most of the protesters are younger than the debate itself.

According to the (probably a bit optimistic) numbers provided by the organizers from Fridays for Future, 1.79 million people worldwide took part in the protests, 300,000 of them in Germany alone. A representative study on the March protests in Bremen and Berlin found the following statistics: 59.6% of the participants were female, 51.5% were between 14 and 19 years old, 19% between 20 and 25, 11.3% between 26 and 35, and 18.2% over 35. The study does not account for people younger than 14 years of age. Another aspect the study highlighted was the partakers’ high standard of education: 55.1% had either passed the general matriculation standard (Abitur) or were planning to do so. 32% had already finished a university degree and only 0.9% had no school-leaving qualification at all. On a political scale, the protesters were generally left-wing oriented and supporting the Green and Leftist Party [12].

With growing public attention, climate scientists such as Professor Stefan Rahmstorf from the Potsdam Institute for Climate Impact Research (PIK) started to endorse the movement publicly, backing it up with scientific expertise and credibility. Concurrently to Fridays for Future, other movements formed in support of the children's strike action, such as Parents for Future, Artists for Future, or Scientists for Future. Although she refuses to being labeled the "founder of the movement," Greta Thunberg was—and still is—the voice of the young generations heard globally. In this function, she spoke at the EU Parliament, the UN Climate Summit in New York, and received numerous invitations to talk to politicians all around the world, especially in Europe. With this voice and the wide support of the movement, we should remain curious about the impact that Fridays for Future will have on our future and the future of our home planet.

2 Why Did the Movement Appear?

Fridays for Future is particularly special due to its participants' young age and its fast-growing global occurrence. For both of these peculiarities to come together, fundamental prerequisites are necessary. These can be summarized in the technical achievements of the digital revolution and the influence of globalization. Both digitalization and globalization contribute to forming the truly international (cosmopolitan) community we see today. Not only in Germany but also all over Europe and all over the globe. Here, the internet was vital for the organization of the movement and its rapid success, and what is more, as an "equal opportunity revolution" toward zero-emissions, digitalization directly impacts on climate change and climate change policy alike [3].

The World Wide Web allows young people (also called digital natives) to connect differently from the way their parents and grandparents could. Most importantly, they can exchange personal experiences and knowledge in another technological manner and at different speeds. The second major condition for the enormous success of Fridays for Future is an increasing sensitization of children for our planet and their understanding of its endangerment. Since the last decade, school curricula allow for an education that fosters environmental awareness from early on. This new approach toward nature mirrors the educational approach and lifestyle of many European parents. Many of which, at least witnessed the environmental protests in the 1980s against acid rain and nuclear power plants, and might partially share their discontent with their children about the fact that many of their claims have not yet been addressed. Consequently, the young activists have access to several kinds of information sources to form their own well-informed opinion on environmental issues, then share them and organize a peaceful civil protest, mostly in the form of civil disobedience.

However, two more reasons are important to lead to unleashing the climate school strikes in 2018. First, the growing mistrust of Western societies in their leadership that increased even more rapidly after the refugee crisis in 2015. This event showed dangerous weaknesses in the democratic systems of the European countries and the EU as its supranational organization as well. Several member states disregarded the Dublin Convention and the Schengen Agreement, which raised issues concerning the sustainability of the EU and its treaties. Secondly, viral news images such as the dead body of little Aylan Kurdi or the chaos at the Budapest Railway Station shook the European population [11, 13]. Especially people under 30 years of age started to doubt the ability or willingness of their political leaders to act. The more left-wing youth in Europe, already bitterly disappointed by the handling of the refugee crises, was now ready to protest against "the establishment" that did not take the environmental crisis of the twenty-first century seriously enough.

Besides that, the number of natural catastrophes in 2018 was just as critical. When Greta Thunberg started to strike, she talked about the natural disasters and the forest fires that she perceived as critical back then. In fact, 2018 has been the year with the worst forest fires in history [14], only to be trumped by major fires in the second half of 2019 in Australia and Brazil in particular. The same year, news channels showed frightening pictures of crashed airplanes, helpless refugees, and terrorist attacks, but on top of this one natural disaster after the other.

The majority of the global public only then began connecting the current increase in natural disasters with climate change and identified humankind as its originator. The environmentally friendly (left-wing) youth seemingly waited for an opportunity to act up. When Greta Thunberg started to go on strike, everything fell into place: The technological opportunities of globalization, a sensitization for the environment through education, a loss of confidence in politicians, natural catastrophes, and finally a young idealistic and charismatic schoolkid from Sweden that was—and still is—on a mission to change the world.

3 Timely Assessment of the Movement

It is important that pupils speak out for their political opinions and demonstrate their ideology by taking civil action and responsibility for their future. However, a devil's advocate needs to question if these protests are reasonable in their dimensions. In Germany, Christian Lindner, political leader of the Free Democratic Party, is one of only a few politicians who publicly criticized the movement [8]. His statement that young people should rather go to school and leave environmental issues to professionals, triggered a so-called "shit storm" in social media, and furthermore, resulted in bad press coverage. Yet he raised valid questions. In what way can young people (often underage) contribute to the debate? Should they not study instead of protesting? Should they not acquire skills and knowledge to act on their behalf when their time has come? Moreover, are they not breaking the law when going on a school strike, as attendance is mandatory in Germany as well as in most countries of the world?

The participants of the movement answer that their survival is more important than schooling. They insist that something must happen immediately to counter climate change as it is no myth and the time to reverse it has almost passed. It seems to them that politicians do not take enough action to address the issue adequately. Scientists also express their doubts, emphasizing the students' concerns are justified and supported by the best available scientific proof [9]. The current measures to protect our climate and biosphere are deeply inadequate. The international governments' self-imposed climate goals of the Paris Agreement are worthless without action to achieve them. The Intergovernmental Panel on Climate Change (IPCC) assesses the chance of staying below 1.5 °C of planetary warming by 2050 lies at around 50%. To achieve this, CO_2 emissions must be cut by 50% by 2030 (relative to 2010 levels) and net-zero CO_2 emissions must be achieved globally while reducing other climate-active gases as well [4].

It seems that climate change has only begun to receive serious awareness around the globe. Here, Greta Thunberg has played an important role. Even if she does not claim it, she had—and still has—a big impact on the success of the Fridays for Future movement. It does not generate new facts and innovative solutions in the way science could, but emphasizes the issue's importance and ensures public attention. Consequently, politicians are under public surveillance and feel impelled to act. Yet the success also lies in the mere ability to rounding up millions under the same cause. It is scientifically proven how extremely difficult it is to initiate the collective action required to mitigate and adapt to climate change. This is mainly due to socio-ideological biases that perpetuate public polarization over the topic [6].

However, a recent study provides proof that children foster climate change concerns among their parents [5]. This insight suggests that Fridays for Future not only fulfills an important role to ensure public attention but also spreads the environmental message directly through its participants. Needless to say that protests during school hours cannot go on forever. In addition, they most certainly should not have to. However, for the time being, their peaceful strike action fulfills an important task until decision-makers in the economy, society, and politics around the globe will seriously address climate change. We need to come up with sustainable and tenable plans to address the most important issue of our time and harmonize the relationship between humanity and nature.

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Empowering the Earth System by Technology: Using Thermodynamics of the Earth System to Illustrate a Possible Sustainable Future of the Planet

Axel Kleidon

Abstract With the use of the appropriate technology, such as photovoltaics and seawater desalination, humans have the ability to increase sustainably their production of food and energy while minimising detrimental impacts on the Earth system. Focussing on energy conversion and dissipation allows us to compare human activity with Earth system processes at a very general level. Here, I emphasise three points: (i) human activity consumes free energy at orders of magnitude not far away from other Earth system processes; (ii) the most detrimental aspects of human activity relate to its consumption of free energy from the Earth system, rather than generating it; and (iii) some forms of technology, in particular photovoltaics, allow to convert solar radiation into free energy more efficiently than Nature does, which provides a basis for a sustainable future. In summary, instead of consuming free energy, human societies should turn into producers of free energy by the use of technology, thus minimising their impact on the planetary environment.

Keywords Thermodynamics · Earth system · Energy efficiency · Energy conversion · Human activity

1 Energy as the Core Problem

The future of mankind faces a multitude of challenges, with consequences that affect the planetary scale of the Earth system. Global climate change, freshwater scarcity in many parts of the world, the loss of biodiversity, and future energy and food supply are examples of some of these challenges. The multitude of challenges is overwhelming and it seems almost impossible to imagine a positive, sustainable future for humanity. In fact, if we continue on the current path, one can easily imagine a dark outlook on the future of the planet that would seem to destroy the very conditions that are needed for a habitable planet.

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What I want to describe here aims at the opposite: To imagine a positive outlook on the future, in which human societies can sustainably grow, yet minimise their impact on the planetary environment. Parts of this outlook were described in similar, recently published literature [7–9], yet the focus here is to put these parts into the context of envisioning a positive, sustainable future. This future will not come automatically but requires a substantial effort to get away from current technologies and focus on those that empower the planet.

Here, I use the word "power" in its literal physical sense of work performed in time. Power, or the generation of free energy by natural processes mostly driven by solar radiation, drives the dynamics of the Earth system, of the biosphere as well as human societies. Based on this view on energy generation and dissipation, I want to emphasise three points: (i) human activity consumes free energy at levels similar to other Earth system processes (Fig. 1); (ii) the most detrimental aspects of human activity relate to its consumption of free energy from the Earth system, rather than generating it; and (iii) some forms of technology, in particular photovoltaics, allow to convert solar radiation into free energy more efficiently than nature does, which provides the basis for a sustainable future. These forms of technology provide human societies with the means to increase the power generation on Earth, make the dynamics of the planet more active, including human societies. In other words, these technologies make human societies a producer of free energy in the Earth system. Currently, however, most of the free energy consumed by human societies draws energy from the Earth system, thus having a detrimental effect and weakening the Earth system.

To understand this main point, I want to first focus on the central role that energy plays for humans and human societies. Energy is central for humans to be active and do things. Humans need the energy to maintain their metabolisms even when they

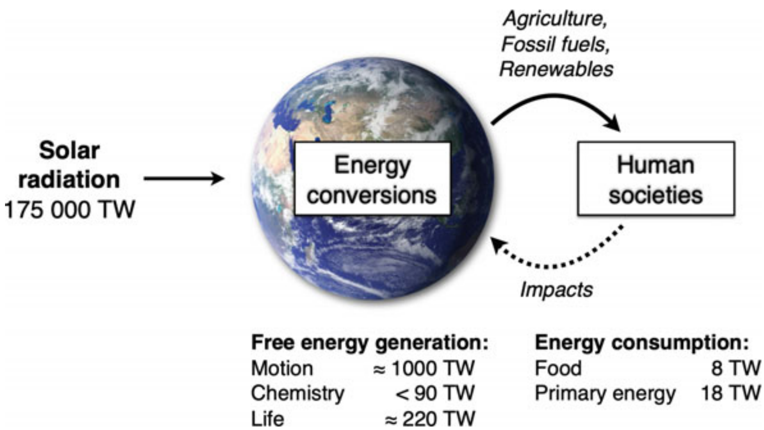


Fig. 1 Human societies consume free energy at rates that are similar to the magnitude by which Earth system processes generate physical and chemical forms of free energy. As human societies currently consume this free energy from the Earth system, this causes detrimental impacts on the planet. Image of Earth from NASA. Estimates from Kleidon [7]. Note that 1 TW = 10^{12} W

sleep and do nothing. Humans get this energy in form of calories from the food they eat. Yet, the majority of energy is needed for socioeconomic activity, manufacturing, transport, heating and cooling, and so on. This energy at present comes primarily from fossil fuels, that is, dead plant material that was sealed off from the active climate system by geologic processes millions of years ago. The combustion of fossil fuels depletes this disequilibrium between hydrocarbons and atmospheric oxygen, it is not sustainable due to its finite size, and the increase in greenhouse gases results in global warming.

This focus on energy makes the activity of humans comparable to the activity of other Earth system processes. I use the term "active" here to refer to this continuous need for energy to do things and maintain dynamics. I approach this from a purely physical, or, more precisely, a thermodynamic perspective. Staying active, thermodynamically, means that processes keep producing free energy in different forms and dissipate these. A focus on this thermodynamically based activity allows us to generalise Earth system processes, to identify evolutionary directions and basic limits, and it allows us to weave human activities that seem so different from purely natural processes into the context of the Earth system. After all, the energy used by human societies needs to come from somewhere within the Earth system, and their activities do something that ultimately alters this very same entity. By tracing energy through the Earth system to human societies and back to the Earth system, one can link these processes together and view them in the context of the functioning of the whole planetary system. We can then appreciate the basic role of humans and their technology and get a glimpse of what we can expect of the future.

2 Thermodynamics Sets the Laws

When we deal with Earth system processes, or processes in human societies, these are typically intimately linked with converting one form of energy into another. Atmospheric motion, for instance, is generated from converting some of the heat by absorbing solar radiation or condensation of water vapour into kinetic energy. This kinetic energy eventually turns back into heat by friction. A plant leaf converts the energy contained in sunlight into chemical energy associated with the production of carbohydrates. Plants, animals, and humans turn these carbohydrates back into heat when they respire it to maintain their metabolic activities. Likewise, technology like power plants or wind turbines are energy converters. A power plant converts the chemical energy of a fuel, such as coal, into heat during combustion, of which a fraction is converted into electric energy that is fed into an electric grid. Wind turbines similarly convert wind energy into electricity. This electric energy is used by human societies and ultimately is also converted back into heat.

These energy conversions follow a strict direction and are constrained by fundamental limits, both of which are set by thermodynamics. The laws of thermodynamics set the basic rules for energy conversions. The first law states that energy in total is conserved when it is being converted from one form into another, while the second law states that energy becomes increasingly dispersed, as measured by the physical concept of entropy.

These laws are fundamental and seem somewhat hidden, but they can be experienced in everyday life. When I start my day with a hot cup of coffee, the inevitable will happen: the coffee will get colder. What actually happens is that the heat, or thermal energy, within the cup and my office are spread more and more evenly, which eventually results in equal temperatures (and cold coffee). During this redistribution, energy stays conserved (the first law), but the entropy increases (the second law). The increase in entropy caused by a process that spreads energy is a fundamental consequence of a process being active. This not only happens with cups of coffee but with all processes in the Earth system. The increase of entropy sets a fundamental direction for anything that happens on Earth, and the speed at which it happens tells us about the overall activity. All processes follow these laws, the climate system, the biosphere, and human societies, with no exceptions.

There is more to the second law than just setting a direction. It sets limits to how much free energy, energy such as electric energy that is able to perform work and maintain activities, can be generated. This limit can be illustrated by a power plant (Fig. 2). A power plant generates electric energy out of the heat. The heat is generated by the combustion of a fuel such as coal at a high temperature, which is energy of low entropy. The heat that leaves the cooling towers of the plant, seen in the form of the white clouds emerging from them, exits the power plant at a much colder temperature, hence at higher entropy. Overall, energy needs to be conserved, so the heat created by combustion balances the heat lost through the cooling towers and the electric energy being generated.

The second law tells us that not all of the heat from combustion can be converted into power that is fed into the electricity grid. A substantial fraction needs to leave the cooling towers, so that overall, at least as much entropy leaves the power plant as

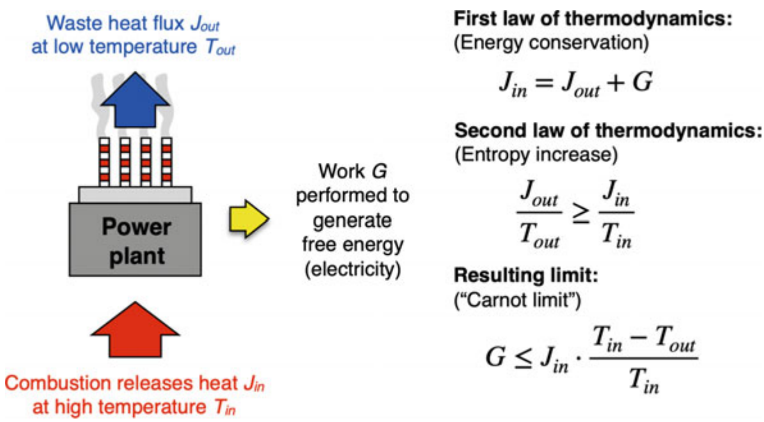


Fig. 2 Illustration of the thermodynamic Carnot limit using a power plant as an example. The equations on the right show that this limit directly follows from the laws of thermodynamics

enters it by the combustion process. In the ideal case, these two rates are equal, which defines the well-known Carnot limit in thermodynamics. It is a direct consequence of the first and second law of thermodynamics. This limit of generation is set by the heat flux entering the power plant, and a fraction, $(T_{in} - T_{out})/T_{in}$, that is set by the difference in temperatures at which heat is added and removed. This fraction is also referred to as the Carnot efficiency.

This limit does not only apply to power plants but also to solar panels; for this, one needs to use the entropy of radiation, e.g., Kabelac [6] and how the Earth generates different forms of energy, for instance when it generates atmospheric motion out of heat. More generally, this limit sets an upper bound to how active a process can be.

3 The Sun Energises the Earth System

When we apply the laws of thermodynamics to the Earth system, it is the continuous input of energy by sunlight that keeps the Earth active. Sunlight is radiation in the visible range of wavelengths. It has very low entropy because it has been emitted by the Sun at a high temperature. After solar radiation has been absorbed, converted and redistributed within the Earth system, it is emitted to space as terrestrial radiation at much lower temperatures, having longer wavelengths in the infrared range and higher entropy. It is this difference in the entropy of the radiation the Earth receives and that it emits that allows for energy conversions and for the Earth to stay active (Fig. 3).

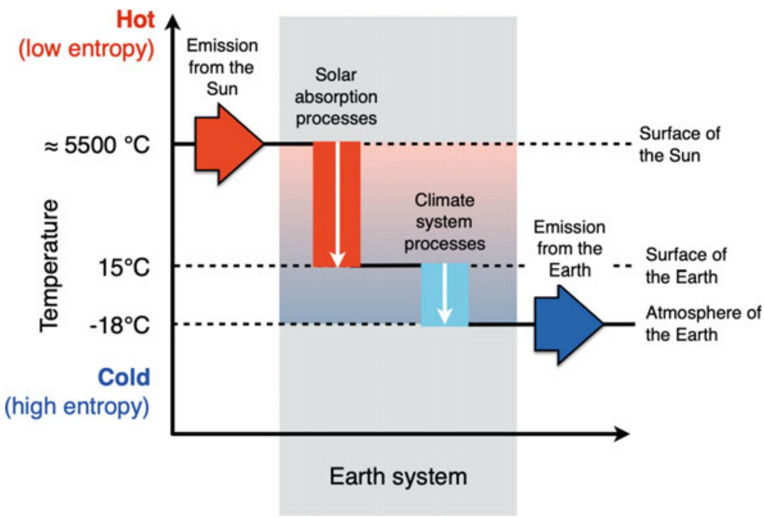
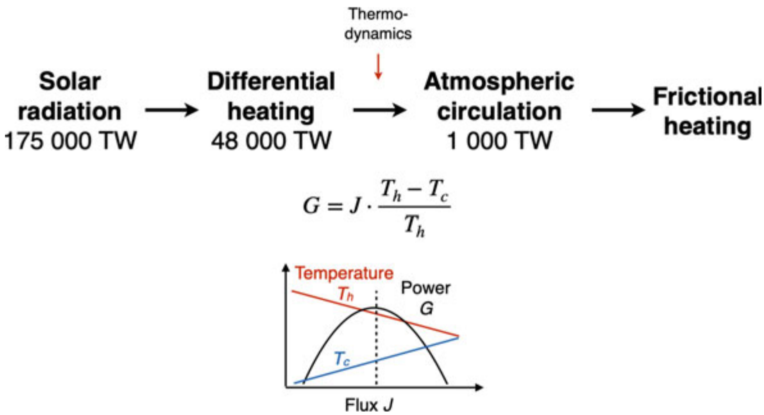


Fig. 3 The degradation of solar energy to higher entropy radiation as it is transformed by Earth system processes

Most of this difference in entropy between solar and terrestrial radiation is, however, destroyed when solar radiation turns into heat upon absorption at the Earth's surface. The difference in radiative heating at warmer places and radiative cooling at colder places can then be used by physical climate system processes to convert heat into physical forms of free energy. These energy conversions keep the climate system active, with organised circulation patterns in the atmosphere, ocean currents and hydrologic cycling. The different forms of energy are generated by sunlight heating the Earth unevenly, thereby creating temperature differences. These temperature differences generate the kinetic energy of atmospheric motion, just like a power plant uses the temperature difference to generate electricity. The result of motion is that the heat it transports reduces these temperature differences, which lowers the ability to generate kinetic energy, or, in thermodynamic terms, it lowers the efficiency of the conversion process (Fig. 4). Simple considerations demonstrate that the atmosphere operates near its thermodynamic limit of maximum power, generating about 1000 TW (1 TW = 10^{12} W) of kinetic energy. This is as much kinetic energy as it is possible to generate. In other words, the atmosphere works as hard as it can and thus staying as active as possible. It suggests more generally that thermodynamic limits not just exist within the Earth system, but that they are highly relevant because physical processes actually evolve to and are maintained at these limits.

Motion, in turn, provides the means for further energy conversions. Upward motions cool air, bringing moisture to its saturation and causing precipitation, thus driving hydrologic cycling. The precipitated water on land dissolves minerals of the continental crust, thus driving geochemical weathering. Yet, the rates by which energy is converted and the sunlight is utilised are comparatively small. The whole atmospheric circulation, for instance, operates by converting <1% of the incoming solar radiation into the kinetic energy associated with large-scale motion. This is



$$G = J \cdot \frac{T_h - T_c}{T_h}$$

Fig. 4 Atmospheric motion results from uneven heating by absorption of solar radiation. The strength of the resulting atmospheric circulation, in terms of the rate by which kinetic energy is generated, is set by the thermodynamic limit and the effect that heat transport has on depleting the driving temperature difference because much of the potential of solar radiation to perform work is lost when it is absorbed and converted into heat. The resulting temperature differences on Earth are small compared to that of a power plant so that relatively little power can be generated.

With photosynthesis, life created an innovation because it does not use heat and temperature differences as a means to generate energy, but it uses the low entropy of sunlight directly. It uses visible light to split water first into hydrogen and oxygen, and then the hydrogen further into its proton and electron. This generates electrical energy that is used to generate chemical energy in the form of carbohydrates and atmospheric oxygen. Photosynthesis generates chemical energy more efficiently than the physical climate system, yet it is nevertheless only able to convert <3% of the energy contained in sunlight. In many regions, biospheric activity is further limited by environmental factors (Fig. 5). In the oceans, mixing limits the supply of nutrients, while on land, the presence of water is a major limitation. This leads to a strong imprint of climate on patterns of biological productivity, and it makes the ability of the biosphere to generate energy dependent upon the work done by the physical climate system. Overall, it leads to a generation of chemical free energy of about 220 TW.

The energy generated by photosynthesis feeds food webs of natural ecosystems, but also geochemical reactions in the Earth system. In fact, life produces substantially more chemical energy than abiotic processes, such as stratospheric ozone

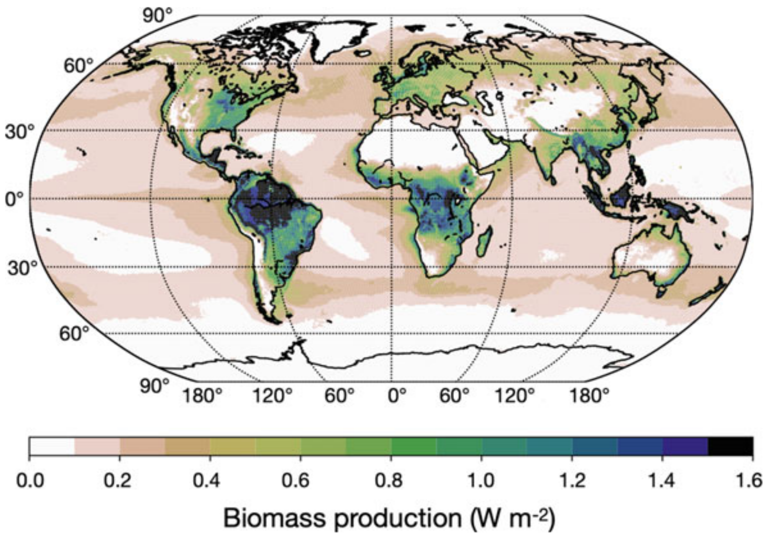
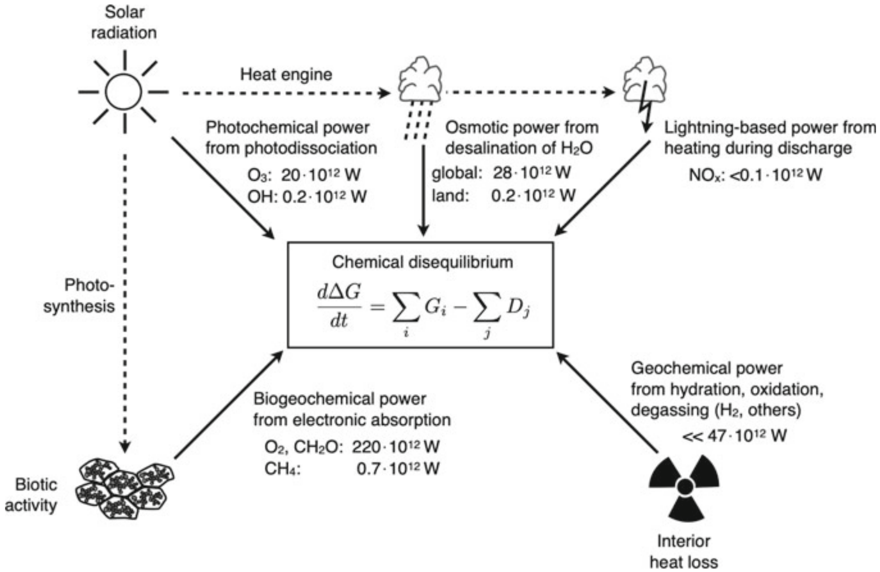


Fig. 5 Mean annual chemical free energy generation by the biosphere in the form of biomass (net primary productivity, photosynthesis—autotrophic respiration), expressed in units of W m^{-2}. The map shows estimates derived from satellite and is taken from http://orca.science.oregonstate.edu/2160.by.4320.monthly.hdf.vgpm.m.chl.m.sst.php (ocean) and https://nacp-files.nacarbon.org/nacp-kawa-01/ (land). Accessed 19 Dec 2018



$$\frac{d\Delta G}{dt} = \sum_i G_i - \sum_j D_j$$

Fig. 6 Processes that generate chemical free energy in the Earth system [7]

chemistry, nitrogen fixation by lighting or geochemical weathering (Fig. 6). Life thus plays a dominant role in shaping the geochemical composition of the planetary environment. This effect on the geochemical composition feeds back to the planetary system because the atmospheric composition affects how well radiation is being absorbed and emitted. This, in turn, alters the heating and cooling rates and thereby the boundary conditions that determine how active the physical climate system can be. As climate limits biospheric activity, this results in a positive feedback by which life changes planetary geochemistry, which alters climate and then allows the biosphere to become more active. This is probably the dominant feedback that shaped the evolution of the climate-biosphere system over the history of the Earth. It likely evolved the biosphere to become more and more active, which allowed it to become increasingly more complex and diverse (see also Judson [5]).

4 Human Activity as a Thermodynamic Earth System Process

When we next turn to human activity in the Earth system, we start with the essential need for energy to maintain human metabolisms and human societies. The calories in food measure the energy that maintains human metabolisms. It comes from the harvests of the energy generated by photosynthesis from croplands and, indirectly, from livestock that grazes on pastures. The energy that fuels socioeconomic activity comes primarily from fossil fuels, stocks of energy contained in plant residues from millions of years ago that did not get decomposed because they were locked away by geologic processes.

To place these two forms of energy consumption by human activity into a quantitative context: The average human metabolism of a 75 kg human consumes about 100 W. Multiplied by 7.7 billion people, this yields a consumption rate of about 0.8 TW. It requires more energy from the biosphere to meet this demand because only a small fraction of plant tissues is suitable to be digested by humans. The use of animal products results in further inefficiencies as it needs to also sustain the metabolic activity of the livestock. Estimates place the actual use of photosynthesis for the metabolic needs of humans at about 8 TW, which represents about 5% of the energy generated by photosynthesis on land (based on estimates by Haberl et al. [4]).

Socioeconomic activity is primarily driven by fossil fuels, or more generally, by primary energy consumption, which averages to a consumption rate of about 18 TW within the year 2017 [1]. It is more than 20 times the metabolic energy needs of humans. The magnitude of this consumption rate emphasises how relevant human activity has become in the Earth system (Fig. 1). Socioeconomic activity consumes more energy than, for instance, the power that mixes the world's oceans, which is about 5 TW. It substantiates the notion that we entered the geologic era of the Anthropocene [2]. Human activity and the associated socioeconomic activity consume energy at rates similar to or even greater than those of natural processes of the Earth system.

From the thermodynamic perspective of the Earth system, the consequences of human activity are fairly straightforward. Human activity consumes forms of free energy that was generated by other Earth system processes, so it depletes associated states of thermodynamic disequilibrium. And this depletion of disequilibrium states is linked with many of the problems of global change.

Using an increasing share of the plant productivity of the biosphere as the energy source to feed the human population means that less energy is available to sustain natural ecosystems and their food chains. The consequences manifest themselves in increased land cover change, reduced wildlife, deteriorated ecosystems and biodiversity loss.

Using fossil fuels as the primary energy source for socioeconomic activity depletes the geochemical disequilibrium between hydrocarbons in geologic reservoirs and atmospheric oxygen. This major form of disequilibrium of the Earth system was generated by the Earth's biosphere and geologic processes over millions of years in the past. As a result of digging up fossil fuels and burning them, carbon dioxide levels in the Earth's atmosphere have increased, causing an enhanced greenhouse effect, global warming and associated changes in the climate system. A cool climate with a carefully regulated greenhouse gas composition does not come for free—it requires chemical work to actively remove carbon dioxide from the atmosphere. This is what the biosphere has done over the Earth's history. Human activities at present undo this work by consuming fossil fuels and by burning up the associated form of disequilibrium.

Human activity is thus, overall, a planetary process that, measured by its magnitude of energy consumption, compares to other planetary processes. Yet, it only consumes energy, resulting in detrimental effects that deplete the planetary state of disequilibrium, making Earth less active.

5 Imagining a Sustainable Future

Let us now get back to the original motivation and the question of how one can imagine a sustainable future from this thermodynamic perspective. Energy consumption is deeply engrained in socioeconomic activities. It is needed for heating and cooling, to build and maintain infrastructures, to produce, transport and trade resources and goods, and transcends most human activities. While increases in efficiency can reduce human energy consumption to some extent, a forced reduction in energy consumption is likely to have devastating consequences for human societies.

So if the current level of energy consumption is going to be more or less maintained or needs to grow further as the world population and standards of living rise, how can this demand be sustainably met? By its magnitude, it compares with other Earth system processes, so how can that much free energy be made available to human societies without detrimental effects on the Earth system

The answer to this question is human-made technology, specifically photovoltaics. Just as photosynthesis, it uses sunlight directly to perform the work of charge separation to generate electric energy. In this respect, it seems to achieve the same goal. Yet, in contrast to photosynthesis, a solar panel does not rely on sources of carbon, water and nutrients as it exports its free energy solely in electric form. Even current, industrial-grade solar panels are vastly more efficient than photosynthesis, using about 20% of the solar radiation, rather than <3% of the solar radiation that photosynthesis can utilise. The theoretical limits of using sunlight of more than 70% will allow for further technological advances and even higher efficiencies. What this signifies is that humans created a major innovation by developing a more efficient process of getting free energy from sunlight than what abiotic or biotic processes have been able to accomplish so far.

To put this form of sustainable energy generation in numbers: To generate the current primary energy consumption of about 18 TW, it would require solar panels with an efficiency of 20% covering about 400,000 km^2 of barren land (about the size of Germany). Given that barren lands cover 19 million km^2 of Earth's continental areas, this represents a small fraction of the world's deserts. On this land, solar radiation would not be wasted by turning into heat upon absorption but would generate free energy to sustain human societies. In other words, it would allow the whole Earth system to produce more free energy.

It would then require little effort to generate even more energy by expanding the use of photovoltaics. This additional energy could be used for desalination to provide more fresh water, more than the natural hydrologic cycle can provide. For desalinating seawater, evaporation requires about 2.5 MJ for each litre of seawater, which then provides fresh water when it rains out. Desalination technology uses membranes, and so the energy requirement to desalinate seawater shrinks to merely 6.5 kJ for each litre of seawater [3]. In other words, with human-made technology, one can enhance the hydrologic cycle by having more efficient options for desalination than how natural processes generate fresh water.

This additional energy and water, made available by human technologies, could then be used to expand agriculture either in the desert regions or in the form of vertical farming, which grows crops in warehouses on multiple shelves with artificial lighting and closed water and nutrient cycling. This would take food production to unprecedented levels, as it can take agricultural production out of the naturally constrained environment. This form of technology-based agricultural expansion would reduce the pressure to clear and convert productive natural ecosystems, such as tropical rainforests, to be used for this expansion. It would even allow increasing overall productivity, thus enlarging Earth's biosphere.

With the heavy use of human technology, the Earth would clearly start to look different from its natural state. Yet, it would, overall, be an evolution in which human technology provides means to enhance the free energy generation of the planet, so humans become producers of free energy, rather than merely consume what the Earth has generated. The human species alone cannot accomplish this task because, by nature, humans are consumers of energy, not producers. It needs solar-based technology that is more efficient than natural photosynthesis for this evolution to take place. Overall, it would allow the Earth to become a more active, dissipative system.

6 Conclusions

What I described here is a quantification of the human role in the Earth system that is based on thermodynamics and free energy, energy that is able to perform work. It shows the huge role that humans play in terms of the energy they consume, which is similar in magnitude to many natural processes of the Earth system. It relates many of the detrimental impacts of human activity on the planet to the consumption of energy that the Earth system has generated so that a sustainable future with further growth can be envisioned if human societies turn into producers of free energy by the use of technology. With the use of technologies such as photovoltaics, humans can produce energy more efficiently than natural processes, and this allows for stronger material cycling, for instance in terms of the stronger hydrologic cycle, enhanced agricultural production or enhanced industrial activity. In this sense, through human-made technology, the Earth can, as a whole, become a more active, dissipative system.

What is so easily described here is obviously not a simple task to be accomplished. It would require human societies to make rational choices based on objective—physical reasoning. It would further require to think beyond simplistic cause-and-effect lines of thought, as systems are strongly shaped by interactions, which in turn affect the thermodynamic state of the planet. These interactions do not necessarily manifest themselves immediately, so it also requires a long-term perspective that includes interactions at various scales. In other words, it would require us to think about the consequences in the context of the thermodynamic state of the whole Earth system. Last, but not least, it would require us to accept a certain level of change as well as the associated responsibility for that change, as the Earth system would unavoidably evolve towards an era of human domination.

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Last But Not Least

Recommendations for Action

Peter A. Wilderer

1 Introduction

On March 20–22, 2019, a workshop was held at the premises of the TUM Science and Study Center Raitenhaslach, addressing the questions raised above. The event's title, "Violated Earth, Violent Earth" was intended to remind of James Lovelock's book "The Revenge of Gaia" (2007). Of note, this book is not about intentional "revenge."

Based on intensive discussions in small groups and the plenary, the participants formulated the following recommendations for action with corresponding elaborations.

2 Recommendations for Action

1. **Stop Biodiversity Loss**: To enable humankind's continued existence on planet Earth, it is as important to preserve on the global scale biodiversity function as to prevent further global warming.
2. **Avoid Tipping Points**: To properly describe the Earth system, its dynamics, and changes, chaos theory must be taken into account, especially when it comes to explaining the exceeding of tipping points.
3. **Reformulate Societal Ethics**: To ensure the health of planet Earth, the development of adapted social ethics must go hand in hand with technical and economic efforts to maintain global health.

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4. **Employ Artificial Intelligence**: To avoid ending up existing in artificial-intelligence-dominated slavery, ways must be found to utilize the new tools of the digital age to reinforce human governance of socio-technical and Earth systems.
5. **Fight Ignorance**: The diminution of human misbehavior is to be considered a cornerstone of sustainable development of society, ecology, and human health.
6. **Foster Democracy**: To overcome barriers of existential relevance, humankind is well advised to orient itself toward science-based future perspectives, legitimated by democratic processes.
7. **Counter Alarming Evolution**: To ensure the continuing emergence of creative and inclusive approaches to overcoming existential threats caused by climate change causing global warming, the creation of effective strategies and their successful implementation is a must.
8. **Redefine Global Health**: The human health dimension must be understood as a fundamental assumption for keeping the planet Earth our common home. This means the assurance of human physical and psychological health is a factor of equal importance to protecting biodiversity, stabilizing climate change, and respecting planetary boundaries.
9. **Facilitate Circular Economy**: Based on the assumption that the environment can be considered our "second skin," it is obvious that humankind at large needs to take full responsibility for the preservation of the ecosystem function.
10. **Shape and Create Innovation**: With the risk of a complete breakdown of the Earth system at hand, a proactive approach toward shaping technology satisfying the actual needs of humanity and nature alike must be the leading principle of the "New Enlightenment."
11. **Redefine Education**: To cultivate a sustainable and adaptive form of "New Enlightenment," a strong focus is to be placed on education, which has to transfer not only factual knowledge but also fundamental principles of ethics, arts, and humanities.
12. **Embrace Vulnerability**: Beyond all threats vulnerability of the Earth system and its inhabitants also is to be regarded as a fundamental openness for change and as a basic aptitude for recognizing in time where and how the change of thinking and acting has to take place.

3 Explanations

Ad 1: Stop Biodiversity Loss

To enable humankind's continued existence on planet Earth, it is as important to preserve on the global scale biodiversity function as to prevent further global warming.

Sustaining a critical diversity of species and metabolic processes is a natural provision to prevent a systemic collapse in case environmental conditions suddenly change. In the past, humankind has demonstrated its ability to adapt to very different climatic conditions, hot and cold periods included. The animated nature also is able to adapt. However, processes of adaptation were mostly associated with the elimination of species in favor of those, which demonstrated specific carrying capacities. Species got extinct but not life itself. Obviously, the Earth system has been able to heal itself and maintain a state of resilience. As Ernst v. Weizsäcker in his introductory speech insisted, time is ripe to understand but not undermine the self-regulation capacity of the Earth system. It is more than necessary to take action to understand the intrinsic dynamics of the animated nature instead of discussing shortsighted pros and cons.

Monocultures in agriculture, for instance, are comparatively susceptible to external impacts. They need chemical or microbiological interventions to maintain stable conditions. The results of unstable conditions are well known, for example in the case of agricultural monocultures. Likewise, a kind of "monoculture" in economic systems is taking hold in the assumption that growth of such systems guarantees efficiency. To keep such systems in a stable state, for example in the form of subsidies, interventions are unavoidable, thus leading eventually to collateral damages. The global community is called upon to steer away from entertaining economic monocultures for the sake of short-sighted financial advantages.

Ad 2: Avoid Tipping Points

To properly describe the Earth system, its dynamics, and changes, chaos theory must be taken into account; especially when it comes to explaining the exceeding of tipping points.

General properties of many if not all physical and biological processes, even though extremely complex, may be described by effects from *Systems Dynamics.* As Patrick Dewilde outlined in his introductory lecture, most natural processes are highly nonlinear and chaotic, meaning that at any moment small fluctuations can be exponentially amplified under the right propagation conditions. "Tipping points" by which all of a sudden new forms of life appear to arise in this way, or, on the contrary, violent destruction annihilates life.

Run-away evolution can only be controlled by an emergent effect, such as "survival of the fittest" or, from a human point of view, human intelligence capable of activating a proxy that leads to a tipping point (e.g., the school strike initiated by Greta Thunberg, or the rise of Facebook, the iPhone, or even the acceptance of Pythagoras' theorem). Nature owes its ubiquitous and continuous creativity to chaos, and it is a major challenge to human intelligence to generate the necessary momentum, i.e., the tipping point, to counteract the destructive effects of the careless exploitation of resources, and the poisoning of the biosphere has created. Even so, there will never be a final solution, and humanity has to keep on evolving with the evolving Earth, using its collective intelligence toward sustainability and optimization of the overall quality of life.

Ad 3: Reformulate Societal Ethics

To ensure the health of planet Earth, the development of adapted social ethics must go hand in hand with technical and economic efforts to maintain global health.

The ongoing developments in science and technology lead to a certain resistance within society, which is often referred to as “Angst” of a potential dominance of autonomous machines. As Klaus Mainzer mentioned in his keynote lecture, we live in an increasingly complex world. An enormous, ever-growing number of data are available ready to be used for solving the pressing problems of today and tomorrow. It appears that the “old” world is disrupted—similar to the situation after the Thirty Year’s War when the first Enlightenment commenced. From that time on, science became the driving force of knowledge gain and technology development. We certainly have not reached the point of ultima ratio, yet. But we are now in the position to enter a new era of science and AI technology which could help us to master the increasing complexity of our civilization. Nevertheless, human governance and responsibility are still indispensable. In this sense, we need a new phase of Enlightenment.

Ad 4: Employ Artificial Intelligence

To avoid ending up existing in artificial-intelligence-dominated slavery, ways must be found to utilize the new tools of the digital age to reinforce human governance of socio-technical and Earth systems.

To reach sustainable development for consistency and purposefulness, it appears reasonable to use the new tools of the information age (artificial intelligence, simulation, scenario analysis, etc.) to, for example, carefully analyze the ever-tighter net of global and regional environmental regulations and incentives set up by different sectors. The purpose is to ensure that they together reach their intended goal and do not unintentionally counteract each other.

Mathis Wackernagel pointed out that regulations resolved by state authorities are only executed and willingly accepted when citizens and executive managers alike realize existential, long-term advantages. Regulations are to be rated as the proverbial “skin in the game.” They become effective by subcutaneous application, as medical doctors might say. The focus must lay on future perspectives rather than on solutions that proved effective in the past.

In this context, it is worthwhile to recall that nature is not a museum but a system in continuous alteration, responding to changing ambient conditions and possibilities. Facing the challenges of the upcoming decades, any legal processes resolved by democratic institutions must provide development processes that appear successful under stressful conditions but allow adjustments and reorientations once novel impacts and scientific knowledge become available. Centrally planned economies, for example, have already demonstrated their inefficiency in many historical cases.

Ad 5: Fight Ignorance

The diminution of human misbehavior is to be considered a cornerstone of sustainable development of societies, ecology, and human health.

The underlying reason for our concurrent global problems is the stone-age old human agency to act against generally approved ethical norms and—more recently—against scientifically proven facts. Just three examples: We know that emissions of greenhouse gases lead to global warming, climate change, and eventually natural catastrophes. We know that agricultural monoculture drives loss of biodiversity and, as a consequence, destabilizes the ecosystem that humankind is dependent. We know that excessive consumption of sugar combined with little physical exercise can lead to diabetes and premature death. We know all this—and much more—but we act against it and then complain about the consequences. Planet-violating forms of consumption have become accepted as a proxy for economic success, although we know that nature is our true indispensable second skin. To break such vicious cycles, it is advisable to use modern communication systems by which means the information does not stay at the cognitive surface but goes "under our skin." Developing means that can positively alter the behavior of individuals and humankind, in general, must be an integral part of the "New Enlightenment" that Ernst Weizsäcker calls for in his report to the Club of Rome.

Ad 6: Foster Democracy

To overcome barriers of existential relevance, humankind is well advised to orient itself toward science-based future perspectives, legitimated by democratic processes.

With democracy, we refer to a process that includes self-determination, inclusion, the opportunity to make up one's own mind, as well as transparency beyond majority voting. We understand democracy as the social decision-making process that is proven to best ensure the emerging of creative and inclusive approaches to problem-solving, the creation of effective strategies, and their successful implementation. Democracy needs to rely on scientific facts that are established through robust, transparent, and testable processes. This enables a society to react open and creatively to changing conditions rather than succumbing to predetermined and imposed choices. This call ("come on") is not only directed at policymakers but at the main acting groups like agriculture, industry, energy, transport, media, the bankers, and, last but not the least, the consumers and voters.

Ad 7: Counter Alarming Evolution

To ensure the continuing emergence of creative and inclusive approaches to overcoming existential threats caused by climate change causing global warming, the creation of effective strategies and their successful implementation is a must.

Our planetary environment changes in an alarming way. Experts assume the carrying capacity of the (global) environment has already been exceeded and the survival of human civilization is ultimately endangered. Global warming and climate change represent just one range of threats planet Earth is confronted with. The human species itself may be able to adapt to higher atmospheric temperatures as well as environmental destruction. Those damages are caused by heavy storms, excessive rainfalls, or flooding, for instance, and also the loss of human lives and property value. The recovery of biodiversity loss may take much longer than human civilization is able to compensate for artificially. In essence, it lies in our own interest to take good care of our "second skin." Proactive health care of our "skin" must play a leading role in the "game!".

Ad 8: Redefine Global Health

The human health dimension must be understood as a fundamental assumption for keeping the planet Earth our common home. This means the assurance of human physical and psychological health is a factor of equal importance to protecting biodiversity, stabilizing climate change, and respecting planetary boundaries.

The working group dealing with public health identified the topics below as the most pressing aspects to address immediately and crucial to reconsider in future dialogues.

Nutrition

Increasing national income correlates with increased consumption of meat. This induces an expansion of the agricultural industry that endangers the climate, the biodiversity, the supply of drinkable water, and the effectiveness of antibiotics. Excessive consumption of meat also implies risks to individual health with increased mortality. We recommend information and education measures, transnational optimization of policies, and market design strategies to limit the damage inflicted on individual health and natural resources.

Aging

The impressive extension of the human life span during the twentieth century relates to the unsustainable use of natural resources. This unsustainable use is aggravated by the lack of evidence-based medicine for the elderly, which in turn results in erroneous and unnecessary therapies. Therefore, we recommend enhancing medical research on multi-morbid old patients.

Public Health

Prevention does not require as many natural resources as therapy. Therefore, we recommend expanding and improving public health efforts in Germany so that the health system reaches the quality found in comparable European nations, whilst keeping in mind that the benefits of a natural environment, that invites us to exercise and enjoy and provides beautiful healthy landscapes, is deeply underestimated.

Allergies

We currently observe an epidemic of allergic diseases such as asthma. This relates to a Western lifestyle implying little contact with a rural environment. The increased frequency of severe disease episodes can be linked to climate change because plants release stress factors with high immunological potential, and thunderstorms drive the distribution and the impact of these factors. In view of this epidemic, we need more specialists for Allergology and environmental medicine.

Pediatrics

Nowadays, children spend most of their time indoors with near-work such as computers and smartphones. This behavior directly relates to the worldwide epidemic of shortsightedness that can be stopped when children spend sufficient time in bright daylight with large distant objects. The effect of smartphones on the mental development of young children requires further research. There might be positive effects because by using the smartphone the child has an additional channel for early interaction with the world at its hand even before being able to speak sufficiently well.

Artificial Intelligence

Artificial intelligence is a highly versatile tool to use big data in prevention, diagnostics, and therapy. However, big data and artificial intelligence are problematic with regard to energy demand and data protection. The further development of AI has to take these problems into consideration—for instance by including analog information coding.

Research

Crises always come along with opportunities. In fact, they frequently provoke the emergence of new development. We, therefore, recommend an optimistic view toward the future instead of fear-driven policies. Research needs to be interdisciplinary, however, so that unexpected side-effects in a complex natural and societal system can be recognized early. Interdisciplinary approaches must, therefore, include the humanities and social sciences, as they have a long tradition of observing the societal part of this complex system.

Ad 9: Facilitate Circular Economy

Based on the assumption that the environment can be considered our "second skin," it is obvious that humankind at large needs to take full responsibility for the preservation of the ecosystem function.

We need to establish a true, circular economy, i.e., a system that lives from within itself and, does not consume resources from the planets' stores or sends waste to third world countries, and that strives to radically extend the lifespan of the products we use. While this is not a new thought, this is now crucial in the light of the increasing speed of innovation and the magnitude of the impact that some of these innovations may have on the planetary system.

The economic system can provide the means and framework for the necessary changes, and concurrently induce corrections to harmful forms of established decision-making.

Economy is a tool, which helps regulate the exchange of goods and services. On the other hand, the Earth system including biodiversity and ecosystems are the baseline for our economic systems. If they collapse, the economic system also collapses. Correction measures are mandatory. Integrating biodiversity and ecological concerns requires an overhaul of the taxation and subsidy system. In this context, it is necessary to consider the dangers associated with the volatility of the financial markets and the resulting threat for the sustainability of any system. This is best addressed on the EU level or higher.

While from a general direction it may be clear, what needs to be done, in detail this is much more difficult and additionally complicated by the human factor human and the human-to-human relationships. We need leadership and the courage to step forward. Especially the young generations are demanding this. While stepping into leadership may feel risky, not doing so will probably not be much riskier either the greater risk. Changing the system and implementing measures will require smart tactics, including hard measures as well as soft ones, and strong consideration of collaboration techniques making sure that all interest groups feel heard.

Ad 10: Shape and Create Innovation

With the risk of a complete breakdown of the Earth system at hand, a proactive approach toward shaping technology satisfying the actual needs of humanity and nature alike must be the leading principle of the "New Enlightenment."

We have to recognize that human demands are overwhelming the capacity of the natural systems, putting at risk our life support system. Apparently, the original concept of the "Enlightenment" no longer suffices to react adequately to the concurrent global challenges.

In this context, one key element is a prospective shaping of technology to humanities actual needs, in German "Technikgestaltung." Elements to successfully implement solutions for a robust, sustainable Planet Earth depend on taking a proactive approach toward shaping and creating innovation, policy, design and technology development (as opposed to post-mortem technology assessments). Examples include assessments that required greenlighting from technology teams, financial viability teams as well as ELSA (ethical, legal, ecological, and societal) teams. A meaningful Technikgestaltung requires interdisciplinary and holistic education in natural science, technology, and humanities.

Ad 11: Redefine Education

To cultivate a sustainable and adaptive form of a "New Enlightenment," a strong focus is to be placed on education, which has to transfer not only factual knowledge but also fundamental principles of ethics, arts, and humanities.

Enhancing environmental education is the main "soft sustainability" measure that can be taken. Education has to take place at all ages, countries, and professions. Advanced methods of education are especially important, as current regulatory systems are much slower than the rate of innovation. A strong focus is to be placed on sustainability within all curricula developing human consciousness and responsible behavior. This could be done through education and training from the earliest age, not only on sustainability at large, but also risk evaluation, and complexity understanding.

This is not only about children, but very much about adults too—learning to ask the question: how do we want to live in the future?

Ad 12: Embrace Vulnerability

Beyond all threats, vulnerability of the Earth system and its inhabitants also is to be regarded as a fundamental openness for change and as a basic aptitude for recognizing in time where and how the change of thinking and acting has to take place.

The vulnerability of the Earth system and its inhabitants corresponds, on the one hand, to the very real dangers and potentially catastrophic developments in the ecological crisis. On the other hand, vulnerability represents a fundamental capability to sense and to adapt to novel developments. In the case of humans, it is their vulnerability that drives them to come up with countermeasures in time. This may mean that they enter proactively into the era of a "New Enlightenment." However, their vulnerability does not predetermine the specific kind of their response. Consider the following controversy: Many assume that the Earth system is basically good and that to end human ecological misbehavior is all what is needed to overcome the current environmental crisis and to return to the paradise they imagine to have existed before man misbehaved. This stance amounts to a fundamental conservatism and, in fact, can claim some good reasons since the Earth system as it used to be, has been working up to now. Thus, a "New Enlightenment" may just end in strict conservatism. Yet, upon more extended inspection of the planet's past, the Earth system turns out to be not so friendly after all, having a history of horrific catastrophes, which endangered large parts of mankind but were not man-made. In view of this history, some people strongly argue against a conservative retreat to the deceptive mother Earth. Instead, they see the current period of unprecedented scientific and technological productivity as an opportunity to prepare for coming disasters, man-made or not, so as to be able to defend mankind against any detrimental conditions to which it will be exposed. This stance amounts to a progressive technicism that will not shrink from global interventions if they appear rational. Such technicism builds on the characteristic feature of man to shape the conditions of his life. However, it tends to misjudge its ability to detect side effects, as the twentieth century has shown. A "New Enlightenment" that deserves the name will stay clear of paralyzing conservatism on the one side and uncontrolled technicism on the other (Fig. 1).

Fig. 1 Participants from Left to Right: Dr. Ulrich Hildebrandt, Prof. Dr. Eckehard Binas, Prof. Dr. Konrad Oexle, Prof. Dr. Felix Unger, Dr. Birgit Herbst-Gaebel, Prof. Dr. Markus Disse, Prof. Dr. Michael Molls, Prof. Dr. Heidrun Behrendt, Dr. Agnes Limmer, Gabi Toepsch, Prof. Dr. Klaus Mainzer, Prof. Dr. Mathis Wackernagel (front), Dr. Martin Wilderer, Jessica Westermayr, Paul Beckh, Dr. Klaus Arzet, Prof. Dr. Hans-Curt Flemming, Prof. Dr. Jörg Völkel, Prof. Dr. Wolfram Mauser (front), Prof. Dr. Ernst von Weizsäcker, Jaroslava Wilderer, Prof. Dr. Peter A. Wilderer, Prof. Dr. Martin Grambow, Dr. Jane Korck, Prof. Dr. Michael von Hauff, Prof. Dr. Andreas Klinke, Willi Kiefel, PD Dr. Jörg Wernecke, Prof. Dr. Hans-Peter Zenner, Prof. Dr. Patrick Dewilde; not in the picture: PD Dr. Ingo Borggräfe, Prof. Dr. Radu Grosu, Prof. Dr. Florian Heinen, Dr. Marcel Huber, Prof. Dr. George Illiakis, Prof. Dr. Eva Lang, Prof. Dr. Jutta Roosen

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Personal Message from the Authors

Michael von Hauff

This collection of articles results from a scientific conference at the TUM Study and Science Center in Raitenhaslach from 20 to 22 March 2019, entitled "Violated Earth—Violent Earth. Causes and Effects of Human's Misbehavior and Nature's Power." Merely by coincidence, this event, featuring several decades of Peter Wilderer's stimulating sustainability research, concurred with his 80th birthday. Therefore, we, the contributors to this volume, want to take this opportunity and cordially thank our editor-in-chief for his lifetime's work.

During the course of his career, Prof. Dr. h.c. mult. Peter A. Wilderer left many marks not only in the scientific but also political sphere: He contributed to the advancement of his scientific discipline and pushed the boundaries of his scientific work to include more interdisciplinary and holistic ideas. He inspired not only scientists and scholars but also practitioners and politicians through his ability to think out of the box and beyond, integrating insights from the technical, natural, and social sciences.

The greatest honor for Peter Wilderer's scientific achievements is the Stockholm Water Prize 2003, which was awarded for his excellent research targeted toward designing a more sustainable water and sanitation future. He has been and continues to be a pioneer in inter- and transdisciplinary work and emphasizes the need for scientists to advise and inform policy-making. He has been strongly influenced by the experience of the Dahlem conferences at FU Berlin when he was a young researcher. During that time, he started to enjoy and cherish the mutual exchange between and beyond the disciplines.

Because of this experience, he founded the IESP—Institute for Earth System Preservation—after his retirement from the Technical University of Munich. His

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ambition has been to foster transdisciplinary research and communication and inspire innovative thinking for the benefit of nature and human society. Directed toward the goal of solving humanity's self-made problems by providing feasible, practical solutions he has been an active change agent toward introducing more sustainable practices in Earth system management. Consequently, strategies for sustainability of the Earth system, is a foray of more than ten years of IESP thinking.

Given his visionary approach toward science, he has set the stage for many younger scholars to pursue the path of a scientific career directed toward progress in sustainable development. Besides his pushing boundaries and fostering a holistic picture, he has a talent for recognizing original thinking and encouraging it in other people, especially young, even if he disagrees. In this way, he could catalyze such a vibrant and diverse community as IESP where all people feel valued and different perspectives nourish each other (rather than compete) across disciplines, countries, and cultures.

Not only his scientific partners and colleagues but also many decision-makers that received practical advice from Peter Wilderer express their gratitude for his restless efforts in advancing science and caring for the Earth system as our common home. They all hope he will remain healthy and energetic in the coming years to continue leading the academic and practical communities toward a more sustainable future.

On behalf of all contributors to this volume:

Konrad Oexle, Patrick Dewilde, Martin Grambow, Birgit Herbst-Gaebel, Agnes Limmer, Anastassia M. Makarieva, Wolfram Mauser, Michael Molls, Ortwin Renn, and Michael von Hauff.

Index

P. A. Wilderer et al. (eds.), *Strategies for Sustainability of the Earth System*, Strategies for Sustainability, https://doi.org/10.1007/978-3-030-74458-8

S

T

U

V

W

X