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ORIGINAL PAPER

Health as temporally extended: theoretical foundations and implications

Ari Schick[1]

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Abstract This paper seeks to develop a theory of health that aligns with the shift in contemporary medical practice and research toward a temporally extended epidemiological view of health. The paper describes how such a theory is at the core of life course based approaches to health, and finds theoretical grounding in recent work in the philosophy of biology promulgating a process theory of life.

Keywords Health · Epidemiology · Disease · Process ontology · Philosophy of medicine · Philosophy of biology · Human temporality · Life course epidemiology · Life course health development

1 Introduction

Living things, and human life in particular, are necessarily understood in temporal terms. Life begins, progresses through phases of development and senescence, and eventually ends. As François Jacob put it, in contrast to classical physics which is orthogonal to the directionality of time, the life sciences, "incorporates time as one of its essential parameters"(Jacob, 1982, p. 53). From this basic observation it follows that health, as a characteristic of living organisms, ought to be understood in temporally extended terms as well. Although the concept of health is arguably first and foremost a pragmatic concept that helps to align the practice of medicine with particular goals, a coherent theoretical account of health remains an essential project for the philosophy of medicine, and as we will see, it has also received attention within particular research frameworks in the health sciences. The central aim of this

✉ Ari Schick
aschick@gmail.com

[1] Polonsky Library, Van Leer Jerusalem Institute, Jerusalem, Israel

paper is to outline a theory of health that reflects a fundamental ontology of living entities as temporally extended processes and to show how this theoretical account aligns with, and provides a theoretical support for, shifts within medicine toward approaching health in temporally extended terms. These include the incorporation of epidemiological findings within medical practice, the emphasis on managing risk factors and chronic diseases, as well as an emerging research framework within the health sciences seeking an integrated developmental approach to health across the life course.

My intent is not to offer a wholly novel conceptual framework, but to bring together two contemporary approaches, one based in biomedicine and epidemiology, the other from the philosophy of biology, and present them as complementary projects that converge toward a unified theory of health. I begin by briefly exploring the images of medical practice that incline toward or away from a temporally extended perspective on health. I then highlight the incompatibility between a temporally extended understanding of health and the most influential naturalistic concept of health and disease, the biostatistical theory proposed and refined by Christopher Boorse.[1] I then discuss two influential research programs in the health sciences that emphasize the necessity of viewing health in temporally extended terms across the life course, and the conception of health they point toward. Turning to the philosophy of biology, I highlight how different views on the nature of living organisms incline toward or away from an understanding of life, and by extension health, that is temporally extended. I then discuss how a process view of life, as explicated by contemporary theorists, points toward a particular theory of health. Finally, I survey some of the implications of a temporally extended conception of health for how we think about and discuss several aspects of contemporary biomedicine.

2 Foregrounding a temporally extended view of health: from clinical diagnosis to epidemiology

Over roughly half a century, the debate over the concepts of health and disease within the philosophy of medicine has generally foregrounded 'disease' rather than 'health' as the operative notion to define or theorize (Murphy, 2021). Whether this in fact stems from a "traditional axiom of medicine"(Boorse, 1977, p. 542) that defines health as the absence of disease, or perhaps because disease lends itself to neater conceptual analysis, this philosophical focus on disease has,

[1] This paper does not analyze the terms of health and disease (as Boorse's BST attempts), rather, as Lemoine (2015) suggests, it offers a theoretical understanding of what health is, as it emerges from a particular scientific research program, and refines it based on a view in theoretical biology (for further discussion of this "naturalistic turn" see Sholl & Okholm, 2021). A prime example of this "bottom up" approach, taking research in aging as its starting point, was recently offered by Sholl (2021) in this journal. The present paper, though developed too early to fully benefit from his insights, comes to **c**onclusions that are in many ways parallel, and hopefully it can be read in dialogue with his general approach and call to "let a thousand theories bloom" (p.44).

until fairly recently, remained in line with the practical focus of modern medicine. The defining feature of much of the progress made by medical science over the past one hundred and fifty years has been continuous improvement in how we understand and treat diseases, and we can readily imagine a typical encounter between a patient and health care provider in which disease is similarly at the fore. A person has a set of symptoms, they describe them to a doctor who then performs an examination and may order some tests; then, perhaps after consulting with a radiologist or pathologist, the doctor provides the patient with a determination of their being in a healthy or diseased state. At this point those interested in analyzing the central concept wish to clarify under what conditions do we say, or should we say, that this person has a particular disease, or is instead healthy. Proceeding from this paradigmatic moment, the clinical diagnosis, not only foregrounds disease, it pegs the crux of the practice of medicine to a point in time in which such a determination is made and from which further decisions emanate (Giroux, 2015). Even before we begin abstracting toward theoretical analysis, this paradigm has largely relegated the concept of health to the mere absence of disease and limited it to an instantaneous state that can be captured via a cross-sectional measure.

However, this model of the clinical encounter culminating in a disease diagnosis no longer reflects much of what comes under the heading of contemporary medical practice. Advances in biomedicine and improvements in sanitation have shifted the burden of morbidity and mortality from acute pathogenic illnesses to chronic diseases that develop over time and often accompany aging (Mercer, 2018; Omran, 1971). Over the past several decades, in countries with well-developed and funded health care systems, medicine has correspondingly adopted a risk-based epidemiological approach to health management based on longitudinal data, which has come to occupy a central place in the practice of medicine. Healthcare professional today are as much concerned with treating acute conditions as with managing a variety of risk factors—from body mass index, to blood pressure and cholesterol levels—that increase one's likelihood of developing future morbidities, as well as promoting positive protective factors that correlate with maintaining good health (Gray, 2013; Hollander et al., 2020). Beyond this, in the past several decades the temporal scope of epidemiology itself has broadened to consider how various influences or stressors, especially early in life, can have profound effects on future health outcomes far later on (Ben-Shlomo & Kuh, 2002; Ben-Shlomo et al., 2016; Halfon & Forrest, 2018; Halfon & Hochstein, 2002). Taking the perspective of contemporary medical practice and epidemiology as our starting point directs us toward centering health as the operative concept and viewing it in temporally extended terms such that the health of an individual is viewed as a function of their current physiological state together with a cluster of various risk/protective factors, which translate into a set of probable future health trajectories projected on the basis of epidemiological data.

3 Can the biostatistical theory accommodate a temporally extended view of health?[2]

Since it was proposed in the late 1970s, Christopher Boorse's analysis of the application of the terms 'health' and 'disease' within medical practice (what he terms the 'biostatistical theory,' or BST) has remained a perennial touchstone in the philosophy of medicine. The fact that it is returned to again and again in discussions of health owes much to its underlying simplicity. Boorse proposes that for a given physiological state to be an instance of a disease within a given individual it must constitute a significant reduction in functional efficiency (reducing the efficiency of a physiological function that overall contributes to survival and reproductive fitness) from the normal functional range of the individual's matched reference class within the population. Boorse's ultimate stroke of conceptual clarification is to define health in purely negative terms, simply as the absence of disease (Boorse, 1977). Throughout subsequent revisions and clarifications, the negative concept of health has remained at the theory's core (Boorse, 1997, 2014). However, the shift in biomedicine described above toward a focus on health across the lifespan calls into question whether the BST's negative definition of health is adequate, and whether it can be modified to accommodate the ways in which biomedical science has changed.

To understand the pressures that an epidemiologically informed approach to healthcare places on Boorse's negative definition of health, it is instructive to turn to an article by Peter Schwartz (2008) which addresses the narrower issue of risk factors in relation to the biostatistical theory, and makes the case that the BST rightfully excludes the presence of risk factors from counting as disease states. If the term risk factor is understood as attempting to capture non-disease states that statistically correlate with future disease states, then, argues Schwartz, per the BST, the presence of risk factors ought to be excluded from counting as diseases. In making this argument Schwartz focuses on a specific type of risk factor, which we might term 'disease precursor'. These types of risk factors—Schwartz discusses stage 1 hypertension and elevated LDL cholesterol—are on a continuum with indicators of actual disease states and increase risk for related dysfunctions.[3] However, they have not, according to Schwartz, crossed the threshold out of the normal functional range and therefore do not in themselves constitute dysfunctional states.

Keeping true to Boorse's concept of disease, Schwartz argues that the approach of current medical practice to such risk factors is conceptually confused, for the tendency is to view them clinically as identical with the actual disease states that they statistically portend. In fact, however, treatment is indicated not because these are diseases, but only because they tend to escalate into disease states, or because the risk factors themselves, while not yet resulting in a dysfunction, are biological

[2] This section is based on an unpublished paper from 2010, written largely in response to an article by Peter Schwartz (2008) discussed below. A more thorough examination of the challenges that epidemiology poses to the biostatistical theory has since been published by Élodie Giroux (2015).

[3] Giroux (2015) notes that Schwartz mistakenly conflates a physiological marker or indicator with the function/dysfunction itself.

stressors that tend to produce dysfunction later on.[4] Schwartz focuses on these kinds of risk factors in particular because inasmuch as they are treated just like diseases, they are the most prone to be confused and conflated with actual diseases, and create the mistaken impression among a considerable number of people that they have a disease.

Schwartz's discussion, though aimed firmly in defense of the BST, actually reveals the pitfalls of a purely negative definition of health. Since on the negative account of health a person who is not in a disease state is healthy, it follows that people with disease precursor risk factors are axiomatically healthy. By current standards this is counterintuitive as a person with elevated cholesterol and/or blood pressure would not be considered entirely healthy given the statistical likelihood of future dysfunction and lower predicted lifespan, and in many cases they would receive treatment for such conditions (Grundy et al., 2019; Unger et al., 2020). Schwartz acknowledges the problem he has uncovered by noting that medical treatments for a non-disease condition are usually thought of as enhancements, making it seem problematic to regard treating disease precursor risk factors as legitimate therapeutic goals that ought to be covered by insurance and the like (Daniels, 2000). He therefore takes pains to stress that his conclusion that risk factors are not diseases has no practical implications for clinical treatment or social policy. To justify retaining the current practice of treating disease precursor, he turns to a normative account of why we treat/prevent diseases—as a matter of justice—to warrant this kind of preventative medical treatment (Schwartz, 2008, p. 330).

However useful this might be in justifying the treatment of disease precursor risk factors, it leaves us with a theoretical conception of health as the absence of disease that does not match the ways in which health is discussed in contemporary medicine, where health professionals commonly speak of moving people and populations from unhealthy states indicated by risk factors—some of which are, by Boorse's definition, actually healthy—to healthier ones where risk factors are reduced or eliminated. Boorse himself anticipated the objection that his negative concept of health is not entirely adequate for talking about health, risk factors, and preventative treatment. To avoid this problem, he introduces a distinction between 'intrinsic' and 'instrumental' health, and offers that talk of risk factors and prevention falls solely under the latter category:[5]

> One last distinction is vital to our target conception. It is convenient to call it the distinction between intrinsic and instrumental health, or between what is a disease and what tends to produce one. The term 'unhealthy' is used in both senses, often with no risk of confusion. When one speaks of unhealthy habits, like smoking, or unhealthy environments, like New York, these are of course items that produce poor health, not exemplify it. But among phys-

[4] Other examples of disease precursor risk factors not discussed by Schwartz might include certain precancerous lesions or polyps. As with stage 1 hypertension and high cholesterol, the preventative treatment for these may be similar or identical to treatments for the actual disease states such as excising potentially cancerous growths.

[5] Schwartz's neglect of Boorse's own attempt to explain preventative treatment is perplexing.

> ical states, it is easy to confuse diseases with dispositions to become diseased under certain conditions…
> This intrinsic-instrumental distinction is often of no consequence in medical practice. Usually physician and patient want to eliminate conditions that are unhealthy in either sense. But failure to draw the distinction is fatal to an analysis of health as the absence of disease. If whatever can cause disease were itself disease, everything would be a disease, since any causal connection is possible in a special environment. The correct strategy is to deal first with intrinsic health by examining what physicians call disease. An analysis of promoting or conducing to health then automatically follows, but not conversely (Boorse, 1977, p. 553).

Once committed to the idea that the concept of health (in the intrinsic sense) refers only to the absence of disease, Boorse is forced to classify all talk of risk factors, promoting health, and gradations of healthier and less healthy states as referring to instrumental health—those things that tend to lead toward or away from disease states.

To comport with Boorse's analysis and explanation of risk factors, labeling a person with a disease precursor risk factor as unhealthy should correspond conceptually with an extrinsic, instrumental relationship between an effect (future disease) and its causes. Yet the most natural construal is that medical professionals speak of such risk factors as intrinsic aspects of health, particularly in the case of disease precursors which are not extrinsic and instrumental, but intrinsic physiological states. Were our concern limited to risk factors that were precursors, it might be possible to simply expand Boorse's negative definition of health slightly to refer to the absence of disease and disease precursors; the latter, being intrinsic physiological states rather than extrinsic causal factors, could perhaps be conceptualized as dispositional (Fuller, 2018), while behavioral and environmental risk factors would remain excluded from intrinsic health. However, apart from undermining the simplicity that makes the BST so attractive, this would not overcome the more fundamental incompatibility between an epidemiological conception of health and the BST suggested in the previous section.

In an incisive critique, Élodie Giroux (2015) points out that Boorse's initial choice to proceed from an analysis of what medicine calls disease and leave health defined as its absence reflects his view of physiology as the basis of modern medicine and the pathologist's understanding of health and disease as dichotomous states. This, as noted earlier, is increasingly out of step with the epidemiological turn in the practice of medicine, which has expanded the focus of medicine far beyond the prevention and treatment of disease to a variety of factors that tend to promote or degrade health, including 'instrumental' factors like behavior and environment (see Broadbent, 2013, Chapter 10). Furthermore, because it is based in longitudinal data and is predictive, the epidemiological view sees health constitutively in the present from a temporally extended perspective partly in terms of a set of probabilistic future states or trajectories. The BST, in contrast, relies on a cross-sectional physiological indicator of pathological deviation below a

threshold of functional efficiency in its definition of disease, which in turn is used in the negative to define health.[6]

By conceptualizing the key terms of medicine as built upon the kind of determination made by a pathologist or as the crux of a clinical diagnosis, the BST limits health and disease to binary states localizable to a particular time point within the body of a patient. It cannot accommodate a concept of health that extends to future trajectories or one that does not necessarily distinguish between internal physiological states and external influences as constitutive aspects of health. An analysis proceeding from the current epidemiologically inflected terms of medical discourse would more plausibly begin with the concept of health itself. This is precisely what some of the work that we now turn to does, as it seeks to better integrate an epidemiological perspective within the health sciences.

4 Life course epidemiology and life course health development

Within biomedicine, a move toward viewing health in temporally extended terms across the lifespan by tracing longitudinal data on health determinants and long-term outcomes has been consolidated under two closely related rubrics: the field of life-course epidemiology, or LCE (Ben-Shlomo & Kuh, 2002; Ben-Shlomo et al., 2016), and the conceptual/research framework of life-course health development, or LCHD (Halfon & Forrest, 2018; Halfon & Hochstein, 2002).[7] Broadly, the idea of the 'life course' shared by both (which has origins and applications outside of health research) is the image of:

> a complex set of interlocking trajectories, or pathways, over the life span of an individual (from conception to death), within and between several domains (e.g. residential, household, family, schooling, work, nutrition) that are marked by sequences of events, transitions and exposures (ETXs) across (and within) the biologically- and socially-defined life stages (or phases) that comprise the human life span. Traversing life stages and moving between them, while expe-

[6] To be clear, at a theoretical level the BST will make use of longitudinal measures in order to determine what counts as a significant loss of functional efficiency. A cross sectional survey of a population will only reveal the distribution of a given measure of functional efficiency; it will not tell you what level of loss of efficiency actually results in a loss of biological fitness in terms of survival or reproductive success (Boorse takes these to be the primary goals that organisms have evolved to accomplish); for this, longitudinal data is needed.

[7] LCE and LCHD can be viewed as parallel research clusters (the former centered in the UK, the latter in the USA) but a full discussion of how they intersect and differ is beyond the scope of this article. A textbook framing the LCE approach to chronic disease was published in 1997 (Kuh & Ben-Shlomo, 1997) and a highly-cited article describing the emerging research program was published in 2002 (Ben-Shlomo & Kuh, 2002). That same year the LCHD cluster published its own programmatic outline (Halfon & Hochstein, 2002) and about fifteen years later each group sought to consolidate the state of the field and vision for the future of the research program; for LCE, a special issue of the *International Journal of Epidemiology* (Volume 45, Issue 4, 2016) and for LCHD an edited volume (Halfon et al. 2018). I focus more on LCHD due to the degree of conceptual framing it offers.

riencing unique sets of ETXs at each stage, defines an individual's life course, theoretically producing differential outcomes (Alwin, 2016, p. 989).

A life course approach views health from a developmental perspective over the entirety of the human lifespan, attempting to take into account complex interactions between biological predispositions and environmental contexts, often with a focus on risk and protective factors that come into play during developmentally sensitive periods such as gestation and pre-pubescence, or factors that build resilience and contribute to healthier aging. In addition to identifying risk/protective factors that influence health trajectories, life course health research seeks to zero in on specific biomarkers that indicate sub-optimal health trajectories with the hope of intervening during stages when wider developmental plasticity is still possible (Hanson et al., 2016). Notably, in describing the need for a life course approach, the framers of LCHD characterize existing disease-centered research paradigms, in both medicine and epidemiology, as inadequate to the task of explaining "what it means to be healthy, how health develops over the lifespan, and the impact of health on the lives of individuals" (Halfon & Forrest, 2018, p. 19).

Advocates for LCE and the LCHD framework argue that they provide increasingly salient models for organizing and structuring investigations into the determinants of health and studying the efficacy of various interventions on health outcomes (Boyce & Shonkoff, 2016; Halfon et al., 2018a, Sect. 4.1). Looking at longer-term trends, there appears to be good reason to believe that the kind of synthesis that life course approaches aim to foster will gain practical support simply from the explosion in the quantity of longitudinal health-relevant data being generated and analyzed. The diffusion of new genetic screening technologies (many now offered direct to consumer) and forms of ubiquitous biomonitoring, coupled with the creation of large behavioral/locational data sets (including those collected by data-driven internet advertising platforms) generate data that may reveal a plethora of previously undiscovered risk and protective factors that come into play through the course of one's life.[8] Frameworks like LCE and LCHD that can usefully develop explanatory models and suggest targeted public health interventions (in addition to improving individualized medical care), will be necessary to insure that the influx of 'big data' into medicine does not merely result in a large-scale fruitless cataloguing of assorted causal factors (Broadbent, 2013, Chapter 10). As the future of medicine becomes increasingly intertwined with longitudinal data collection and analysis, the health sciences may well incline toward a more integrated perspective that can "guide future scientific inquiry on health development and facilitate a long overdue and needed synthesis of medicine and public health—a synthesis that links treatment, prevention, and health promotion" (Halfon & Forrest, 2018, p. 20).

LCHD integrates a conceptual framework that draws on ideas from biological systems theory and organismal development together with an applied research

[8] This image of an emerging state of constant health surveillance and risk assessment is, to say the least, problematic, but the subject for a different discussion.

agenda centered in epidemiology. The architects of LCHD offer a corresponding 'definition' of health around which the project centers:

> Health in the LCHD framework is defined as an emergent adaptive response to environmental (e.g., biological, behavioral, family, social, physical) challenges. The dynamics of health development and the emergence of diseases, dysfunction, or disintegration depend on dynamic processes and patterns of responses that typically span from the cellular to the whole person level. Because no component of this cluster of interdependent processes and purposeful relationships is ever standing still but is in a constant state of dynamic fluctuations, *health is recognizable in the organism's dynamic developmental adaptability and their capacity to strategically respond to different environmental challenges.* (Halfon et al., 2018, p. 640, emphasis added)

The first definition (an emergent adaptive response to environmental challenges) appears far too broad to suffice as a definition of health, but later in the passage the framers of LCHD gesture toward an underlying theory of health (my emphasis), which as I will show, emerges from a basic ontology of life. In the next sections I describe this approach from the philosophy of biology and then suggest how a theory of health derives from it.

5 Temporality and the process ontology of biology

Having proposed at the outset that time is essential to understanding biological phenomena, the metaphysical suppositions of this idea require some elaboration—both to support this contention and to better understand why temporality can be easily overlooked when proceeding on other theoretical grounds. When we think about what exists in the world, the intuitive notion is that the world is largely filled with various *things*: inanimate objects like houses, tables and chairs, and living things like plants, nonhuman animals, and people. An ontology in which the basic category is *thing* does not need to incorporate time as one of its essential parameters, for time does not necessarily factor into the qualities that are essential to a particular thing being what it is. If living entities are kinds of things, then they must be conceptualized first as things, and secondarily as things which undergo certain processes of growth and development that are characteristic of life.

In recent years, John Dupré and other philosophers of science have made a compelling case that this view leads to a fundamental misapprehension of the nature of life (Dupré & Nicholson, 2018). The basic nature of a thing is that it is static and has fixed boundaries. One can easily tell where the chair ends and the table begins; and over time when a chair breaks, or a table rots, these changes are deviations from a normal fixed state which characterize the object in question, not essential qualities. However, this is simply not true for living entities, which are characterized in fundamentally temporal terms: they are dynamic, they continuously change, and as explained further on, their boundaries are often not clearly defined.

The alternative that they champion, a processual view, proposes that living entities ought to be classified not as objects or things, but fundamentally as *processes*:

> organisms, despite their apparent fixity and solidity, are not material things but fluid processes; they are metabolic streams of matter and energy that exhibit dynamic stabilities relative to particular timescales. As processes, and unlike things or substances, organisms have to undergo constant change to continue to be the entities that they are. (Dupré & Nicholson, 2018, p. 17)

In other words, when viewing organisms at the macro level and over a short timescale, it is easy to perceive them as stable and thing-like. However when we peer down to the level of biochemical reactions and cellular functions, we immediately see constant change. Similarly, when we take a temporally extended perspective, rather than fixity, we see developmental change as a fundamental characteristic, rather than accidental feature of the organism. As Nicholson expounds, the fact that organisms do not behave purely mechanistically is precisely because they are not thing-like entities that obey the billiard-ball-like rules of nature described by classical physics. Such a misconception is a residue of the successes achieved during the scientific revolution by focusing on things that do follow such rules. The corresponding atomistic description of the natural world came to be seen as the fundamental representation of how nature works, and living entities were thus viewed as things which undergo various processes, rather than processes in and of themselves (Nicholson, 2018).[9]

When we turn to health, we encounter further implications of this ontology. If organisms are objects, it would not necessarily be mistaken to think of health and disease as conditions that can be localized to one particular time. Health and disease could thus be understood as properties of organisms viewed at a single time point (with the caveat that even a cross sectional 'snapshot' of health must be derived from physiological function over multiple time points; much like an instantaneous function in elementary physics). By contrast, if the starting point is that biological entities are processes, it would be incongruous to define a process as healthy solely based on how it is functioning at just one slice of time. Rather, health would best be conceptualized from a temporally extended perspective and understood both in terms of the current state of an organism-process and its trajectory projected into the future.

[9] Morgan argues that one can arrive at a similar view proceeding from substance ontology, in which living systems are likewise "temporally extended, dynamic, ecologically dependent, and have vague boundaries" (Morgan, 2021, p. 13). Although he convincingly shows that advocates of process ontology overstate the inflexibility of various explications of substance ontology and the intractability of attendant metaphysical puzzles, none of this undermines what I understand to be their central claim, that 'process' is a better fit for characterizing the essential nature of living organisms. Indeed, to a large extent, what contemporary process ontology attempts to counter is not a sophisticated version of substance ontology, but a 'folk' substance ontology that carried over into the life sciences from other scientific domains. Such ontological presuppositions can profoundly change how one characterizes, for example, 'development' (Fabris, 2018). For present purposes the more salient consideration is what ontological claims are reflected in the relevant biomedical theories and frameworks. Here, the life course frameworks are marked by a shift toward an underlying processual understanding of the organism and health. Still I am sympathetic to modesty when it comes to claims about what *really* exists, and for those so inclined, Pradeu argues that the processual view ought to be understood as an epistemological viewpoint while remaining agnostic on ontology (Pradeu, 2018).

6 From process ontology to a theory of health

A theory of health that better comports with how health is discussed in contemporary medical practice, in the field of life course epidemiology, and in the life course health development framework, would have to accommodate the wide range of epidemiological risk and protective factors identified as significantly impacting health throughout one's life. Many types of risk factors, such as Boorse's examples of smoking and living in an area with elevated levels of air pollution, would properly be described as behavioral or environmental, and would not normally be thought of (using Boorse's distinction) as intrinsic to the state of an organism. Yet, as mentioned earlier, under these rubrics they are not viewed as merely instrumental, extrinsic causes of future good or ill health, but as aspects of health viewed in the present as well. How then would one justify the notion that a probable future state, some of whose salient causal factors are external, could be understood as an intrinsic aspect of health in the present—even absent a clearly identified causal pathway? In order to arrive at a theory of health that justifies viewing health through a temporally extended lens and successfully integrates current physiological states with behavioral and environmental factors, we need to more fundamentally consider the nature of the biological organism as described in the processual view.

Recall that this ontology of life proposes not only that organisms are living processes rather than atomistic things, but that such processes do not have entirely fixed boundaries. Take for instance the increasing recognition of the importance of the gut biome for human health. The fact that we rely on the presence of some trillions of microbiota to help regulate digestion and the immune system is but one indication that as living processes we do not function as closed systems, but are rather intertwined with other processes occurring within and around us (Dupré & Nicholson, 2018, p. 24; see also Hutter et al., 2015).[10] Similarly, although on the surface we typically see rigid differentiation between an organism and its surroundings, a process view sees the borders between the individual and the external environment as fuzzy, with the organism's survival dependent on continually taking in inputs and energy from the environment. Once the border between organism-process and environment begins to be effaced, a rigid division between intrinsic and extrinsic (or instrumental) factors which appears as a clear distinction regarding a thing/object, is no longer decisive. In place of the intrinsic/extrinsic distinction, a process view would more properly ask what is or is not a *constitutive* aspect of a given process, and propose a gradation of relevant factors that ranges from genome, morphological structure, and metabolic and physiological function, to the environment and behavior, all of which can be understood as properly constitutive of a person's health—both in the present and projected forward.

[10] Morar and Skorburg (2018), while not proceeding from a processual view, offer a similar rejection of strict individuation (in part based on the integral importance of the microbiome) and explore the implications of their theory of "extended health". The implications of the microbiome for our understanding of health has also been addressed by Inkpen (2019).

Turning to the question of integrating an individual's possible future functioning into an assessment of current health, process ontology is similarly important. Following a process view, an organism cannot be understood in relation to a single brief time period, but in terms of different timescales, depending on what aspect of the dynamic biological process is being examined.

> From the point of view we are advocating, the organism itself is a process, specifically a developmental process. Development is not something that happens contingently to the organism; it is a core and structuring activity without which the organism could not be the kind of process it is (Bertolaso & Dupré, 2018, p. 331)

Whereas the health of a discrete physiological process might be assessable between two adjacent time points, the health of the overall human organism as a developmental process can only be viewed at a far more expansive timescale. At the developmental timescale of the human lifespan a person surely cannot be characterized solely as healthy or diseased, but rather as more or less healthy in relation to a reference population or an idealized norm of what a healthy life, complete with senescence and death, looks like.[11] That is not to say that looking at functional aspects of health at particular time slices is not heuristically valuable, but it does not capture what it means overall for a developmental process to be healthy.

This brings us finally to the question of how to conceptualize health in a manner that comports with a temporally extended developmental viewpoint. Following the processual view, and echoing the LCHD framework's "dynamic developmental adaptability," health can be understood as follows:[12]

> Health is the capacity of an organism to maintain the kinds of dynamic stability that it requires to proceed through its continuous development (i.e. over its life-course), in relation to both its environment and its goals (henceforth the Life Course Process Theory of health, or LCPT).

As far as the meaning of *dynamic stability* in reference to a developmental process, Fabris defines it in terms of *homeorhesis* (a concept described by C.H. Waddington):

> Homeorhesis, like homeostasis, also refers to the regulatory ability of a system to reach a dynamic form of stability by compensating against perturbations within a specific range of responses. The difference is that, while a homeostatic response concerns the maintenance of a single, fixed steady state,

[11] Schwartz struggles with some of the counterintuitive implications of the definition of a disease changing based on changes to the reference class over time. Compared to traditional hunter-gatherer societies everyone today is at higher risk of cardiovascular disease, but we would not want to say that nearly everyone harbors a dysfunction and therefore is diseased (2008, p. 328). This problem is easily avoided once we conceptualize health beyond the mere absence of disease and can talk about relative states of healthy and less healthy. This, along with other considerations motivates Schroeder's (2013) argument that health is a comparative concept, which is fully compatible with the theory of health I describe here.

[12] Although Dupré and Nicholson (2018) and Bertolaso and Dupré (2018) discuss aspects of health and disease in relation to process ontology, they do not formulate an explicit definition or theory of health.

> a homeorhetic response refers to the stability of the temporally extended trajectory of the system… Homeorhesis is, in a sense, a more general biological property than homeostasis, as it maintains the organism in a stable state over the course of its development by means of a range of specific homeostatic responses.[13] (Fabris, 2018, pp. 253–254)

Apart from a shift in emphasis toward a more temporally extended developmental conception of dynamic stability, the LCPT parallels contemporary theories of health that center on some notion of dynamic equilibrium, such as Ananth's evolutionary-homeostatic concept of health (2008), and Dussault and Gagne´-Julien's related conception of health as an organism's disposition to homeostatically maintain its designed functions (2015).[14] Closer still is Sholl's (2021) theory of health as a "landscape of optimized phenotypic trajectories" which builds on the concept of homeodynamic space (Rattan, 2020).[15]

Although the LCPT is compatible with these homeostatic/homeodynamic theories of health, the introduction of the idea of *goals* allows it significantly more flexibility. Those who favor a more strictly naturalistic view of health will be inclined to limit such goals, following Boorse, to survival and reproduction. However, the LCPT allows us to incorporate a far broader set of goals as we move up the chain of organismal complexity. At the level of human beings, the scope of such goals can expand to include a broader conception of objectives and flourishing (Law & Widdows, 2008; Venkatapuram, 2013).

At the very limited timescale of a cross sectional measure, the absence of disease certainly factors in to an assessment of a person's health, but the temporally-extended conception of health proposes that since health is a characteristic of a developmental process viewed across the life course, in an idealized sense an individual's health at a given time point incorporates a forward-looking theoretical projection of their probable future health trajectory as well.[16] This trajectory would be plotted as a statistical distribution of possible outcomes (be it for one particular

[13] As a reviewer noted, the definition offered by Fabris as maintenance of a "single, fixed steady state" does not reflect how homeostasis is described in the literature, particularly given that many biological systems can function well within a certain range of values (Kotas & Medzhitov, 2015). However, the intent, per Fabris's understanding of Waddington, is to capture how an organism maintains stability through a developmental course that exhibits a great deal of plasticity.

[14] Both Ananth and Dussault and Gagne´-Julien, without emphasizing a shift in the locus of analysis, similarly turn from an analysis of disease to one focused on health. Both theories, it should be noted, see in Boorse's own analysis an overlooked underlying theory of homeostasis.

[15] This convergence emerges both from the 'bottom-up', as research on aging over the past two decades has been influenced by life course approaches to health and wellbeing (Ben-Shlomo et al., 2016; Hanson et al., 2016; Kuh & the NDA Preparatory Network, 2007), as well as at the theoretical level, where one finds parallels with Waddington's process-based developmental theory of phenotypes as "temporally extended epigenetic trajectories" (Fabris, 2018, p. 246).

[16] Dussault and Gagne´-Julien (2015), in a parallel manner, incorporate a forward-looking aspect of health by characterizing it in dispositional terms, as does Werkhoven (2019). I favor the term *capacity* as better capturing a property like health which manifests in different ways under different conditions and at different levels of analysis (e.g. individuals and populations). On the relationship between a process view of life and a dispositional account of causation see Anjum and Mumford (2018).

physiological parameter or using a more comprehensive model like 'health adjusted life years') using the range of inputs that bear on health—everything from genetics and early developmental influences, to behaviors, environmental conditions, and assorted stressors.

Clearly our ability to access such information and our knowledge of how it correlates with the ongoing dynamic stability of the human organism is vastly incomplete. The predictive models that epidemiology offers today can only be thought of as rough stand-ins, in which population-level statistical data is brought to bear in an assessment of an individual member's probable trajectory. Hence, to say that a person who engages in an unhealthful behavior like smoking is themself unhealthy, prior to the appearance of any dysfunction, is to make a claim about the person's probable health trajectory, with the caveat that although it is likely that at some level the capacity to maintain dynamic stability is already being compromised and the individual is on a sub-optimal trajectory, it is possible that the individual in question is an outlier who will suffer no such ill effects (and is thus *healthier* in certain respects than the reference population given their greater capacity to resist the effects of smoking). In other words, although within this theory health is ontologically well-defined, in many cases we are epistemically limited to probabilistic claims about it.

7 Implications of the life course process theory of health

Our discussion has shown that a temporally extended understanding of health emerges from an underlying process view of life, and that this view of health as a capacity of a developmental system to maintain dynamic stability matches the conception of health at the center of two life course based approaches to health research, life course epidemiology and the life course health development framework. This tracks how these approaches draw on ideas from biological systems theory and organismal development (Halfon & Forrest, 2018), which can be seen as ultimately reflecting an underlying process view as well (Griffiths & Stotz, 2018).

Not surprisingly, since the LCPT reflects many of the theoretical commitments found within the LCHD framework and LCE, the practical implications that flow from the LCPT will generally tend to comport as well. A temporally extended conception of health across the life course sees health fundamentally as a variable capacity that characterizes development over time (which for heuristic purposes we often describe in more temporally segmented terms as moving through various developmental stages). The primary practical concern of those proceeding from such a theory will be the extent to which a given person (and from a public health perspective, population) has sufficient health capacity at each stage to achieve developmentally appropriate functions across the lifespan.

Again, it should be emphasized that unlike the BST, the LCPT conceives of health in a manner that is largely independent of how we define disease, and in fact, significantly relegates the importance of disease as a principal concept. Rather, the LCPT is concerned with events and exposures that produce long-term reductions in one's health trajectory, which the LCPT theorizes in terms of a reduction in the

individual's capacity to maintain dynamic stability. Where some deficits in health may be characterized as diseases, temporary reductions in function that result when the body is devoting resources to fending off infection or recovering from injury can be thought of as essentially healthy. On the other hand, even absent what we would normally characterize as a disease, when the capacity to maintain dynamic stability begins to break down or stressors accumulate in ways that suggest that the dynamic stability of the organism will be compromised in the future, the LCPT sees this already as a relative loss of health, albeit one that at some point may be inevitable.

7.1 The boundaries of medicine and priority setting

Although it breaks sharply from a focus on disease, the LCPT allows us to retain practically useful definitions of disease, such as the BST's pathological deviation from species typical function. The life-course view thereby does not need to give up on the attendant advantages of a strictly delimited disease definition upon which clinical judgments ought to be based, such as allaying worries that the term disease can too often be applied in politically and socially oppressive ways.

However, with the concept of health largely made independent from the definition of disease, we can no longer apply a strict health/disease dichotomy to neatly distinguish between what should and should not fall under the purview of biomedical practice. To be sure, as Schwartz essentially conceded, with the rise of treatments for risk factors, its use in that sense had already become quite limited. However, the LCPT appears to make it even more difficult to delimit what falls into the category of health and what does not, for as we saw, it readily blurs distinctions between intrinsic physiological or genetic factors and extrinsic factors such as environment and behavior. Should a theory of healthcare justice, for instance, wish to rely on a prior independent analysis of health to decide what kinds of resources should be incorporated under the category of healthcare and what ought to be taken up under some other rubric of distributive justice, it will quickly run into problems under the LCPT. For example, once it is understood that an array of ecological, environmental, and social conditions, from poverty, to air pollution, to the overabundance of highly-processed foods, have unmistakable detrimental effects on health, the purview of healthcare can appear to become overly expansive. However, this is less of a concern once we simply concede that deciding which determinants of health ought to be addressed via the healthcare system itself is not a job for a prior theory, but a practical question of which sectors (healthcare, social welfare, environmental protection, etc.) are best equipped and most effective at tackling a given issue.[17]

Although the LCPT is not suited for line-drawing, if we shift the perspective to one of priority-setting it can be applied more constructively. At a practical level, one of the more compelling reasons to develop a clearer conception of health lies in the increasingly difficult task of differentiating between treatments that maintain

[17] Morar and Skorburg's (2018) extended concept of health similarly begins to efface the boundary between the individual, population, and environment. Their suggestion for how to delimit the proper bearer of health relies, in part, on where efficacious biomedical interventions are targeted.

or restore proper health and those that do not, and by extension which ought to be prioritized or funded with public resources devoted to healthcare. It should not be surprising that the LCPT view, aligned as it is with an integrated perspective from epidemiology and public health, prioritizes prevention over treatment and early interventions that improve health trajectories throughout a person's life. This follows conceptually from seeing health as the capacity to maintain dynamic stability through development over the lifetime. Whereas the biostatistical theory would point to healthcare as promoting health by preventing or treating disease, the LCPT allows for a more robust conception of health that admits to gradations of health beyond merely being free of disease, and would favor setting a reasonable optimally achievable level as a theoretical goal beyond what is presently found in a local reference class (e.g., in reference to contemporary populations with well above average measures of health and lifespan). Conversely, the LCPT is less favorable to interventions that are out of sync developmentally or do little to promote or restore dynamic stability.

For example, the proper functioning of the immune system can be seen as a prime example of an organism maintaining dynamic stability in response to perturbances that ensue from its interaction with other organisms. Hence, other things being equal, the LCPT fundamentally prioritizes vaccination over treatment of acute disease as coming closer to the ideal of maintaining health. In line with this, and apart from any potential practical advantages, the LCPT might point toward devoting resources to developing alternatives to current transplantation medicine in which one instability (a rapidly failing organ) is replaced by another (a slowly failing organ and suppressed immune system) not simply as being practically superior, but as holding closer to its core conception of health.

Similarly, since the LCPT sees the function of the human microbiome as an integrated part of the human organismal process and intrinsic to its dynamic stability, it views the health of a person's microbiome as an intrinsic aspect of health. This gives us a clear basis for taking assaults on the health of the micriobiome, whether stemming from caesarian birth, diet, excessive sterilization of the environment, or antibiotic use, as seriously as other insults to human health. Concomitantly, an intervention that directly attempts to restore a stable population of gut symbionts, such as fecal transplantation, would no longer be conceived of as an exotic last-ditch remedy after antibiotic therapies fail, but as a first line therapy (Morar & Skorburg, 2018). As a practical matter, judgments about such priorities may seem to rest primarily on matters of efficacy and costs, but we should not discount how underlying ideas about the nature of health may subtly orient clinical and policy judgments in different ways.

The LCPT view of health also helps us to make sense of how the term 'disability' is deployed. Where the BST simply avers that disability is a condition that maps on to certain chronic disease states given various social and ethical considerations (Boorse, 2009), the LCPT allows us to conceptualize disability without recourse to the idea of disease. The concept of disability generally can be seen as mapping onto conditions in which a person is born with or acquires a functional deficit but overall is able to regain a new kind of dynamic stability.

To be sure, I am not suggesting that the LCPT conception of health does all, or even most of the work in the realm of priority-setting, healthcare allocation, or medical decision-making. My intent, rather, is that having a temporally extended developmental conception of health as a shared basis for discussing many of these issues would go some way to fostering a more productive dialogue. To the extent that conflicts surrounding these issues can be exacerbated by an underlying lack of agreement about what health is, a common understanding of health offers a better starting point for coming to some consensus about difficult cases.

7.2 Reproductive health

As decisions surrounding the creation of new human beings are among those carrying the greatest moral weight, we should be skeptical of the idea that a concept of health is going to offer decisive practical guidance. Moreover, the application of the concept of health to human reproduction is vexing at a number of levels. Looking at nonhuman animals, it is fairly easy to identify where reproductive health may be compromised, particularly at the population level. But for humans, there is an increasing mismatch between how we have evolved to reproduce and the ways in which people would ideally choose to do so given social factors and personal preferences. Apart from the effects of individual reproductive choices to delay having children and to have fewer of them, environmental factors that may be driving losses in fertility for both men and women further obscure the picture of what reproductive health ideally looks like throughout an individual's life. Additionally, viewing health across the lifespan must account for how pregnancy and childbirth produce short term health risks but also correlate with longer-term protective factors, and perhaps even longer lifespan overall (Modig et al., 2017).

Given these considerations, should reproductive health be framed solely in reference to the natural reproductive capacities of a theoretical human population that follows reproductive strategies shaped by evolutionary (rather than social) pressures, including expected declines in women's fertility through middle age leading up to menopause, or should cultural shifts and changes in procreative goals be granted standing as well? The LCPT does not fully answer these questions, but it does point to a different practical emphasis. Much that goes under the heading of reproductive health focuses on acute problems that arise when people who desire having children run into difficulties, and many of the ethical debates arising in this area likewise surround the use of technologies brought to bear to address infertility. A temporally extended theory of health such as the LCPT would urge reframing reproductive health as a feature of a developmental process over one's life, with greater concern for events during earlier sensitive periods (such as exposure to endocrine disruptors) that may have significant downstream consequences for reproductive health. Although it would allow us to set an idealized trajectory of reproductive health as a theoretical target, at its core, a developmental view of individual fertility must view a natural decline in female fertility relatively early in the human life course (compared to many nonhuman mammals) as expected and healthy (Matthewson &

Griffiths, 2017, Sect. 6). Like the life course itself, the developmental process of reproduction is characterized by a natural peak, senescence, and ending, and maintaining health will mean different things during different periods.[18]

Finally, from the perspective of a process view of life, the reproductive timescale extends beyond the individual lifespan to the subsequent generation produced. The LCPT view therefore points to a longer-term perspective that factors down-generation effects into decisions about reproductive health and managing fertility. At the same time, even as life course frameworks better integrate epidemiology and public health with clinical medicine, we ought to recognize places where individual reproductive health and population-level reproductive health can diverge, such that the health of the population is not a simple function of the aggregate health of its individual members and can in fact run counter to one another. At the population level, if dynamic stability is seen as the primary measure of reproductive health, then declines in fertility that partly offset increased offspring survival rates would be a healthy development, however, such declines may result from a relative loss of reproductive health at the individual level. Again, this points to the limits of a theoretical conception of health in areas where normative theories of individual flourishing, intergenerational justice, or environmental ethics should be leading the discourse.

7.3 Healthy aging

As with reproduction, the interaction between the concept of health, aging and the end of life in the context of modern healthcare is puzzling, albeit for different reasons. Even with advances in healthcare, declines in health that accompany aging are universal and death itself remains as unavoidable as ever. What confuses things is that while in practice, healthcare providers often apply a concept of health that is relative to age (e.g., 'healthy for an 80 year old woman/man'), the main paradigm for interventions often remains the treatment of disease, or essentially anti-aging, rather than healthy aging (Rattan, 2013; Sholl, 2020). The LCPT view of health offers a theoretical framework that clarifies the underlying concept of healthy aging as seeking to maintain the kinds of dynamic stability reasonable for the later developmental phases marked by senescence. Once again, this points to prioritizing interventions which seek to maintain dynamic stability, with the understanding that dynamic stability looks different as the body begins to senesce (Sholl, 2021).

Because the LCPT approach to health is built on a developmental-processual view, it is also better suited to conceptualizing the later sections of the life course as a natural aspect of human development rather than as a pathological deviation from earlier periods of better health.[19] Characterizing aging as part of a developmental process alerts us to the need to better equip practitioners to deal with its distinct

[18] However, as mentioned above, the incorporation of a broader, normative understanding of human goals is also compatible with the LCPT, allowing one to integrate changing reproductive goals and an expanded timeframe of healthy fertility.

[19] Against those who characterize aging itself as a disease process (Caplan, 2005; Izaks & Westendorp, 2003) the LCPT strongly favors the view that it is not (Schramme, 2013), but instead ought to be understood as a developmental stage.

developmental contours. And just as obstetricians and pediatricians see their jobs as primarily that of promoting healthy development rather than specializing in prenatal or childhood diseases, it might benefit the historically underfunded and understaffed field of geriatric medicine to attract money and talent were it more widely understood in positive developmental terms as well. Similar benefits might also accrue on the research side for fields seeking to better understand and manage the biological processes of aging.

7.4 End of life

The final stage of life is of course dying. Here the LCPT understanding of health allows us to conceptualize dying itself as a temporally extended process in which the body progressively loses its ability to maintain dynamic stability culminating with the cessation of the overall organism process itself. At this point, the focus of health providers needs to shift into a distinct mode appropriate for this last stage of the life course. Here, interventions that are normally applied to restore dynamic stability, for instance the use of vasopressors to keep blood pressure up, may in fact be inappropriate as they fundamentally conflict with the process that is underway. Again, the LCPT is not in itself going to offer guidance for end of life treatment decisions, but a common baseline understanding of what dying is, based on which further discussions can proceed more effectively.

8 Conclusion

A life course process theory of health proposes that health be understood in temporally extended terms as an organism's ability to maintain dynamic stability over its life course in a manner that is appropriate to its developmental phase, environment, and goals. Because this theory emerges from a processual understanding of the nature of living entities, it has the advantage of being rooted in an ontology of biology, while reflecting a contemporary epidemiological understanding of health as expressed in research programs like life course epidemiology and life course health development. Among its notable features, this view offers what it is essentially a naturalistic account, but by expanding the scope of an organism's goals, it is possible to integrate normative perspectives a well. It is also compatible with various definitions of disease, while maintaining that under certain circumstances a disease state is not by definition unhealthy, and generally shifting the focus of biomedicine toward health as its operational concept. Although it is not intended to offer a comprehensive approach to the range of issues that touch on how we value and promote health, it can provide a shared understanding upon which constructive discussions of these topics may proceed.

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