Postdigital-Biodigital: An Emerging Configuration

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1 Introduction

As the world approaches the first anniversary of the Covid-19 pandemic, biology, chemistry, physics, and other traditional disciplines in the natural sciences converge in the concept of technoscience and the transdisciplinary 'nano-bio-info-cogno' paradigm (Bainbridge and Roco 2006). Social sciences and humanities explore emerging concepts such as biodigital philosophy, postdigital knowledge ecologies (Peters et al. 2021a), bioeconomy (Peters et al. 2021b), viral modernity (Peters et al. 2020b) and others. Educators and develop 'emergency remote teaching' responses (Hodges et al. 2020) as well as broader and deeper concepts such as precision education (Williamson 2019) and postdigital ecopedagogies (Jandrić and Ford 2020). Disciplinary convergences, development of new concepts and of course online learning, have been around for a long time. Yet it is fair to say that no area of human activity, and no area of intellectual work, has remained untouched by the Covid-19 pandemic.

During the fateful year of 2020, Michael A. Peters, Petar Jandrić and Sarah Hayes have extensively contributed, as authors and editors, to these research efforts.

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As we move beyond immediate responses and take our first stabs at more general questions pertaining to our (post)-pandemic reality, our work, separately and together, has surfaced some important themes and questions. Based on our previous works on collectivity, including but not limited to interconnected notions of knowledge socialism (Peters et al. 2020a, b) and postdigital dialogue (Jandrić et al. 2019), we decided to explore these themes in a trialogue. Keeping each individual voice, our trialogue seeks a common ground between its authors' positions and exposes various cracks and tensions. While we tremendously enjoy rare occasions when we have arrived at a full agreement, it is within these cracks and tensions that we see room for development of our individual and collective work.

Our first theme concerns clarification of the main concepts and terms. Pandemic responses require urgency, so it is hardly a surprise that recent works have paid more attention to ideas than to precise ways of expressing these ideas. Yet ideas cannot be divorced from concepts, and concepts cannot be divorced from language. It is with this understanding, that we undergo an exploration of relationships between various concepts such as postdigital, biodigital, bioinformational and so forth – concepts which, we feely admit, have been used in rather non-systematic ways even in our own recent works. This discussion of concepts and terms brings about our second theme: convergence. After decades of experience we are already well-used to 'low-level' convergences such as biophysics and technoscience, yet their mutual combinations and 'higher-level' convergences such as 'nano-bioinfo-cogno' (Bainbridge and Roco 2006) still leave us baffled. How do we make sense of something, which is at the same time everything else? Our third theme, education, offers a way of approaching new concepts and convergences at their point of intersection in educational praxis.

2 The Many Faces of Postdigital

Sarah Hayes (SH): I had been wondering about the reconciling of postdigital and biodigital, and I think it is very helpful to debate the use of these terms. As we have applied the idea of postdigital, we have used the proviso that it is useful, adaptable but an imperfect, partially developed concept. '[A]s we have already discovered with posthumanism and postmodernism, the prefix post(-) signals that we have something to talk about.' (Sinclair and Hayes 2019: 129) I have always thought of the concept of the postdigital as ontological as well as epistemological, with authors bringing all manner of interpretations connecting diverse traditional and contemporary theories. Do you envisage biodigital as a progression on from postdigital, or a break with postdigital, given biodigital is such a major shift?

In *Postdigital Science and Education*[1] I have really liked the inclusivity aspect of the community using a messy notion, where people have shaped an ongoing

[1] See https://www.springer.com/journal/42438. Accessed 5 October 2021.

'postdigital dialogue' (Jandrić et al. 2019). So, my other question concerns 'biodigital dialogue' and your thoughts on how you see it shaping?

Michael Peters (MP): I am not sure I can answer these questions but postdigital operates in some way as a critique of the digital as a technological fix as I argued in one of my papers (Peters and Besley 2019). Postdigital also implies that other arrangements are possible so for me to informatize biology (bioinformatics) is only one interaction or integration; the other is biologizing information such as organic memory. When that happens as it will more often, then, we move from epistemology to ontology, i.e. humans are open to becoming something different, to evolving into biodigital beings. What that means is still in the making – new forms of synthetic life that may also be part of humans.

Surely this is postdigital but it is also an evolutionary advance on the digital that can become human – an open possibility. When the convergence goes through many iterative cycles in the next decades it may mean a new form of genetic-digital intelligence where conversation and dialogue are more easily facilitated perhaps through direct thought transfer. I'm not a futures scholar and also I am neither trained in biology or computing, but we have seen many 'generations' in both – what new developments occur will depend on new waves of innovation and development. But the integration – not sure this is the best word – certainly means new plants, modified animals and modified humans. And it does potentially make possible bioeconomy that is environmentally self-renewing. This surely is significant when facing the prospect of mass extinction. But we need to think more about this question.

Petar Jandrić (PJ): As a group of us wrote in our first postdigital paper, '[t]he postdigital is hard to define; messy; unpredictable; digital and analog; technological and nontechnological; biological and informational' (Jandrić et al. 2018: 895). In my view, bioinformation and biodigitalism are intrinsic – and very important – parts of the postdigital idea. I would argue that postdigital is indeed, as Michael said, a critique of the digital as a technological fix. Yet I would also argue that the postdigital is much more than that – it is a wide-open position or perhaps even worldview which encompasses various reconfigurations between technologies and humans. This applies to all kinds of technologies, including but not limited to biodigital technologies. So for me, the biodigital is an important aspect of the postdigital idea, but it is far from the only one.

Speaking of examples from the conclusion to our 'Biodigital Technologies and the Bioeconomy: The Global New Green Deal?' chapter (Peters et al. 2021b), this implies that technological unemployment and bioeconomic reconfigurations of work are not at all in conflict. Rather, these and other diverse transformations are a part of the same cultural evolutionary shift slowly taking place in front of our eyes. A few years back, the question of the day was technological unemployment; today, it is the Covid-19 pandemic. We, humans, always tend to focus to what seems to 'hurt' us most at any given moment; yet we always need to contextualize our interests into a wider perspective. To continue with the example, we cannot look at technological unemployment without looking at bioeconomic reconfigurations of work (Peters et al. 2019). Since our current interests cannot be divorced from our earlier

interests, our previous work also provides important input for our present work. I think that the concept of the postdigital could be used as an integrating factor, or a 'higher' conceptual plane, at which our interests may come together.

SH: So, if we think of postdigital as Petar describes it, as a wide-open position/worldview 'which encompasses various reconfigurations between technologies and humans', we might debate all manner of other arrangements, interactions, convergence and integration from any stance. In my forthcoming book I explore 'postdigital positionality' and invite debate on broad connections with inclusivity across humans and data-driven technologies (Hayes 2021). I include interactions with my airing cupboard and hot water tank, as one playful example. Static though the hot water tank may seem just now, it could be invited like other material or organic items to become digitally intelligent. As part of the algorithmic internet of things (AIoT) it joins 'a paradigm shift where anything and everything can be interconnected via a communication medium' and 'security is a prime concern' (Pal et al. 2020). Therefore, I question what reforms are needed to inclusivity policies (that still centre around human-to-human discriminatory practices) to now be inclusive of a hybrid assemblage of devices and potential data bias, that humans now intimately interconnect with (Hayes 2021).

We can go further to contemplate too, as Michael suggests, where 'organic memory' might lead and indeed how much 'humans are open to becoming something different, to evolving into biodigital beings'. Given that this is 'still in the making' and 'new forms of synthetic life may also be part of humans', my next question concerns how this now works in terms of subject disciplines and theory? What broader positionalities might we adopt in order to theorise the paradigm shifts evolving and converging in postdigital society? As we have collaborated on articles and books, we have examined the dialectic between technologies and humans through critical theories and made our links to other disciplinary traditions and conventions as well as underpinning political economy. Yet we might wonder now at how disciplines may converge differently under, or across, new bioinformational and biodigital paradigms.

Taking the humanities as one example that has developed branches of digital humanities and posthumanities (Braidotti 2019), this concerns more than simply extending a discipline within formerly agreed traditions. If as Michael discusses 'new plants, modified animals and modified humans' (as well as modified hot water tanks) emerge, how is this interpreted from the perspective of say, art? Many artists have applied postdigital theory which permits argument to develop from any point in time or disciplinary or interdisciplinary viewpoint. These paradigm shifts bring new questions though, such as 'linking art with human dignity' in any 'reconsideration of our traditional notions of nature and the human body' (Zwijnenberg 2014: 131). As technologies and conditions converge into 'algorithmic medicine' what are the implications for 'digital health'? (Petersen 2018). As we contemplate these examples at a philosophical level, there are legal, practical, methodological and ethical questions that cluster, not to mention those concerning research funding bodies and policy.

MP: I don't see conflict between the postdigital condition and biodigital technologies except that one is a 'condition' and the other is a working technology – the result of technological convergence between new biology and digital technologies. Biodigitalism is a broad term trying to work out the lines of convergence going forward and it has been spectacular. It also offers the prospect for bioeconomy that can provide environmental self-renewal and synthetic enhancement. We in the humanities need to understand the principles of 'new biology' and genomic science in particular, in order to discuss the prospect and reality of *biologizing the digital*. This is surely postdigital but a form of postdigital that is not confined to critique and is able to recognize the biological paradigm of the digital.

We get close to understanding this paradigm in artificial neural networks, digital organisms, evolutionary algorithms, evolutionary computation, genetic programming, mathematical biology, neuro-organic evolution and organic computing, to take some recent advances. We can pick up on Dennis Bray's (2011) *Wetware: A Computer in Every Living Cell* where he argues that each individual cell contains thousands of enzymes, each performing reiterative, molecular processes, that act like transistors that can be ordered in pathways, or electronic circuits, to perform logic operations – the equivalent of a natural computer. Bray argues that the most basic form of cellular life exhibits a highly complex computational structure, just like a computer which is crucially important in biorobotics. Thus, as one blogger puts it: 'Organic computers, sometimes also referred to as wetware computers, can be described as computational devices that are composed of organic materials, such as living neurons. While conventional computers can only operate in binary, a neuron can be in thousands of different states.' (van Hooijdonk 2019) Van Hooijdonk also reports on how researchers use clustered regularly interspaced short palindromic repeats, or CRISPR, to create a biosynthetic dual-core computer within human cells, and he indicates that '[t]he first reprogrammable DNA computer has arrived'. This is definitely postdigital in that organic computers may become a viable alternative to silicon-based devices. Researchers have also developed a method to 'genetically' engineer a better type of memory using a virus (Singapore University of Technology and Design 2018).

There are many examples where 'organic memory devices show promise for flexible, wearable, personalized computing' where '[b]rain-inspired electronics with organic memristors could offer a functionally promising and cost- effective platform' (American Institute of Physics 2020). Others have argued for organic molecule-based data storage and neuromorphic computing. Organic memory technology is a new field that demonstrates the power and potential of an aspect of organic computing. As Nau and List-Kratochvil (2015) summarize, 'the ongoing development in organic memory technology based on resistive switching and transistor-based memory from the material development, processing as well as from the device operation point of view'. Building organic computing devices indicates a couple of things; how technological convergence, especially at the nanolevel, creates new paradigm; and the extent to which cultural evolution is driven by the twin forces of new biology and 5G computing. To me this speaks to both the postdigital

and biodigitalism, which has huge implications for education and science especially at the level of cognitive science.

3 Postdigital Convergences

PJ: In 1998, Nicholas Negroponte based his prediction that '[l]ike air and drinking water, being digital will be noticed only by its absence, not its presence' on the following premise: 'Yes, we are now in a digital age, to whatever degree our culture, infrastructure and economy (in that order) allow us. But the really surprising changes will be elsewhere, in our lifestyle and how we collectively manage ourselves on this planet.' (Negroponte 1998) After 20-odd years, it is now obvious that the most surprising changes surpass well beyond Negroponte's predictions. The world has not progressed as far as Ray Kurzweil's singularity (2005), but biotechnologies reach much deeper than culture, economy, lifestyle or collective management. Reaching all the way to questions pertaining to human nature, our biotech present is somewhere between Negroponte and Kurzweil. Biotechnology is foundational to our postdigital condition, inasmuch our postdigital condition creates conditions for development of biotechnology. These two concepts are mutually foundational, and obviously not conflicted – but that does not imply that they are the same. So what can we learn from their mutual relationships?

An obvious point of departure, kudos to Michael, is that 'one is a "condition" and the other is a working technology'. When we develop knowledge about a condition, we are in the realm of science (lest we forget the original meaning of the Latin word *scientia*, which is knowledge). When we develop a technology [defined by the Greeks as the combination of *τέχνη (technē)* and *λόγια (logia)*], we are in the realm of application of science to the practical world. There are many conceptions of both science and technology, and we do need to urgently explore their latest developments in the postdigital world. However, this cannot be done in isolation, as the convergence of biology and information is based on another hugely important convergence of science and technology or technoscience.

In our previous chapter (Peters et al. 2021a) we examined this convergence in more detail and identified several important 'epistemological shifts in the post-war period emphasizing new knowledge ecologies, technologies and research fields, that reflect a set of technological convergences that integrate, multiply, expand, broaden and synthesize existing fields in genomic and information science'. In another chapter (Peters et al. 2021b) we showed close links between biodigital technologies and the bioeconomy, suggesting that identified epistemological shifts are closely linked to (political) economy of (techno)scientific production. This signals that our neatly divided convergences (biology+information, science+technology, etc.) require a meta-convergence. We, thus, arrive to the postdigital convergence of information, biology, science, technology, politics, society and various other phenomena that remain unmentioned. In its original formulation, this postdigital convergence has arrived from our descriptions of the postdigital condition (see Jandrić

et al. 2018), but it equally speaks to 'lower-level' convergences such as science+technology.

Now that we outlined these complex relationships between various convergences and their levels, a crucial question is: What is to be done? Developing possible approaches to our understanding of reality (science) and transformations of reality (technology), I am painfully aware of our human limitations. Rome was not built in a day, and we cannot solve all the world's problems at once – therefore, we need to 'attack' problems one by one. Such approach fits well with the structure of academic publishing, so our analysis of techno-convergence is one research paper, bioeconomy is another research paper… *ad infinitum*. While it is completely legitimate (and often necessary) to focus one's work to lower-level convergences and their consequences, we need to remember that lower-level convergences cannot be fully understood without the higher-level postdigital convergence. For instance, any discussion of the science+technology convergence will be incomplete without consideration of political economy. This reconfiguration of relationships between traditional scientific and technological disciplines is one important point at which our theories of the postdigital condition enrich our theories of biotechnology and vice versa.

SH: This would seem a good point at which to turn this postdigital trialogue about the biodigital implications discussed so far, in the direction of questions concerning language and behaviour. I find myself reflecting on how so much of our postdigital debate has drawn on the consequences emerging from how our political economy is organised, as Petar reminds us above. If our biodigital dialogue draws on bioeconomy, then, will we need to examine 'political bioeconomy' as a new, or extended field of thought, or alternative way that society is organised? How might this look beyond our current political economy? Having closely examined how policy discourse about technology has been shaped through political economy, to limit us within restricted instrumental approaches (Hayes 2015; Hayes and Jandrić 2014; Jandrić and Hayes 2018), I am interested in what new discourses and related behaviours might emerge through political bioeconomy. Rather than a dominant discourse about how technology will automatically enhance experience (as if experience were something universal that we all share), might we discuss new forms of 'political bioeconomic discourse'?

How might these new discourses then contribute to new directions for postdigital debate? These ideas really pick up from where our 'Biodigital Technologies and the Bioeconomy: The Global New Green Deal?' chapter left off, as we called for 'new understandings of bioeconomy fit for our biodigital moment in history' (Peters et al. 2021b). What kinds of reasoning powers will we be likely to require then in a political bioeconomy? In *Postdigital: Using AI to fight coronavirus, foster wealth and fuel democracy*, Thomas Ramge (2020) questions how human beings can use artificial intelligence intelligently. He argues too that 'artificial intelligence will not be able to relieve us of the burden of thinking, nor will it be able to tell us the right way to act socially' (Ramge 2020). Citing the combined efforts of humans and machines to fight Covid-19, Ramge argues from a postdigital point of view that whilst information technology solutions might have assisted in the struggle against the virus,

the human behaviour of social distancing has saved millions of lives. Ramge discusses 'the dialectic of digitalisation', including when governments and political leaders discover how they can use the innovations of surveillance capitalism to manipulate and control people's decisions. Thus, we are left with many tantalising questions concerning how the dialectics of politics, language and behaviour might play out in a political bioeconomy. I am also fascinated to know more about the shape that political bioeconomic discourse might take.

MP: I think biotechnology and biodigital technology are very different: the former is the use of biology to make products which has a specific technological trajectory, while the latter can be regarded more as a philosophical platform for planet Earth as evidenced in principles of bioeconomy – that is, environmental self-renewal and synthetic enhancement. This means that biodigital technologies, or the biologization of digital processes, are a reflection of a very different kind of political economy – a great question that you raised Sarah! In one strict sense, biodigitalism and biodigital technologies must be in sync with principles of sustainability (and the Millennium goals) aimed at the survival of humanity as a whole. (We have come some way now to energy self-renewal systems.)

But this development of biodigital technologies is proceeding unevenly and the pattern of ownership is worrying when big multinationals like Monsanto own genomic rights – where a company can own plants or animal species. These very large biodigital multinational companies cannot be controlled simply through bioethics but require an advanced biopolitics that analyses ownership of the biosphere with rights and ownership, production and evolution, of life itself. In some ways this biodigital development represents the stuff of science fiction concerning 'cyborgs', human/machine clones, robots and AI. In another way, these biodigital technologies indicate that the future has already arrived when one looks at the growth of the techno-state that raises many issues to do with 'techno-politics' and 'techno-science' (Peters 2020a, b). All of this is part of the postdigital – what you get when you biologize the digital, which also means biologizing digital capital. When it goes wrong either by error or design the consequences could be catastrophic because we might be talking about the destruction of an entire ecosystem especially in relation to destructive synthetic biological constructions that get lost in the system.

4 Postdigital Education

PJ: The digitalization of biology, and biologization of the digital, now permeates all aspects of our lives. Virginia Eubanks' (2018) *Automating Inequality: How High-Tech Tools Profile, Police and Punish the Poor* presents powerful testimonies of what happens when algorithmic technologies decide about human destinies. Our *Education and Technological Unemployment* (Peters et al. 2019) points towards biological consequences of changes in the workplace. Shoshana Zuboff's (2019) *The age of surveillance capitalism: The fight for a human future at the new frontier of power* is probably the most detailed study of complex entanglements of

tecno-surveillance and today's capitalism. Yet, I would argue that the biological aspect is probably most prominent in extensive dataification and algorithmization of education (Jandrić and Ford 2020); these days, it culminates in testimonies and analyses of teaching during the first wave of Covid-19 lockdowns (Jandrić et al. 2020, 2021a, b).

Education is often understood as a field that permanently lags behind technological and social development. A few years back, Siân Bayne wrote: 'When we look at the last few decades of thought about the position of the human in the humanities, the social sciences and even in the sciences, it always surprises me how far behind education has remained.' (Bayne in Jandrić 2017: 210) Similarly, Neil Selwyn admits: 'I should confess to not paying super-close attention to the 'education studies' literature in general. I try to read everything but the education literature, as this tends to where the most interesting ideas, debates and discussions about technology (and often education) take place.' (Selwyn and Jandrić 2020: 994) While it is perhaps unusual to look for the latest developments in the field of education, there is a small but rapidly growing body of research exploring the digitalization of biology and biologization of the digital worthy of our attention.

A useful concept to start with is Ben Williamson's 'precision education'. According to Williamson,

> A new interdisciplinary educational science focused on the quantification of students' affects, bodies and brains, captured in the term 'precision education', has emerged as a priority among scientists, foundation funders, philanthropic donors and commercial entities. Set in the context of intensive scientific advances in the biological sciences, including psychophysiology and biometrics, neuroscience and genomics, precision education raises fresh questions about the intersections of biology with society, politics and governance. (Williamson 2019)

Williamson's precision education is based on a trialectic between psychodata (obtained from psychology and psychometrics), brain data (obtained from neuroscience) and biodata (obtained from human genomics). This trialectic is another example of convergence, this time at a very practical level. It is connected with 'new forms of scientific educational research and evidence creation [that] is reconfiguring the conditions for knowledge production, and reconfiguring understandings of the human beings that are the subjects of education policy and governance' (Williamson 2019). It is in Williamson's precision education, that we can see the concept of biodigitalism and our theories of convergence in action.An interesting outgrowth of these developments is the concept of epigenetics, which refers to heritable changes in (human) genes that do not alter the underlying DNA sequence. According to Pickersgill,

> writings from educational researchers, for example, are enrolling epigenetic findings and ideas to support various positions or approaches. These contribute to a vision of biology that aligns closely to often pre-existing ideas about the Good Society and the kinds of policies and practices necessary to reach this. Through disparate writings, then, epigenetics and education are increasingly being made relevant to one another. (Pickersgill 2020: 79)

In the context of Covid-19, Johnson et al. (2020) present 'evolutionary biology and epigenetics as a foundation for an argument for reconfiguring the parameters of

learning and educational organisation'. Precision learning, epigenetics and other educational projects at the fringes of biology and information are now all parts of a wider notion of postdigital education.

SH: Picking up on the question of whether education lags behind technological development is interesting to contemplate a little further through a postdigital lens. Should only a chronological perspective be applied, then it could seem that education just doesn't keep up. For example, thirty years ago Hlynka and Belland (1991: v) argued that it is 'ironic that educational technology, a field which prides itself on being within the vanguard of change, suddenly appears instead to be lagging behind other fields and disciplines'. They added that 'educational technology appears to have become stuck fast in a technological means-end model' (Hlynka and Belland 1991: v). In the disappointing decades that have followed, despite rapid digital progress, this fixed means-end identity for technology within education has been persistently reinforced via policy discourse based on a neoliberal economic model (Hayes 2015, 2019; Hayes and Jandrić 2014; Olssen and Peters 2005). This could now be set to change, as advanced biodigital developments and principles of bioeconomy require education based on environmental self-renewal, rather than consumer consumption (Peters et al. 2021a, b).

Taking a postdigital perspective disrupts the means-end model of rationality and also enables a longer look back. This reflexive review may pick up on historical points that connect with current sustainable goals but it need not be constrained by too chronological an account of education, or education technology. Looking back, but with an eye to the future, this postdigital trialogue that we are currently engaged in connects, therefore, with longer emancipatory educational purposes (Biesta 2009) rather than short-term, means-end processes. In shedding *instrumental* values, our judgements can now be based on *ultimate* values: values about the aims and purposes of education for all citizens (Biesta 2009), as we anticipate what a digitalization of biology, and biologization of the digital, might contribute.

In this way, we might now pick up the strands of educational movements that have persisted, stalled, failed even and re-engage with pre-digital initiatives that support current emancipatory self-renewal goals. Taking its departure point the Declaration of the UN Conference on Human Environment (1972), UNESCO's Education for Sustainable Development: a roadmap (2020: 65) proclaims that 'to defend and improve the environment for present and future generations has become an imperative goal for mankind'. Whilst we don't seem to have done too well on that score overall, there are educational movements and purposes aimed at inclusion and opportunity for all that have persisted, despite funding cuts and attempts to impose simplistic means-end models of progress.

Thus, at the same time as discussing the latest biodigital advances, there are questions to consider relating to the very notion of 'literacy', as it has been enacted so far in relation to citizens, and how it might now relate for example to 'precision education' (Williamson 2019) and the postdigital challenge (Jandrić 2019). What we discuss as literacy in language, digital skills, data or all of these, may now require a new hybrid concept that we need to come up with. New terminology may be needed to help us to visualise, for example, how 'citizen literacy' (Casey 2020)

might develop at the intersections where biology, technology, economy and politics meet. Given that education has always needed a spread of provision and techniques to reach society's most disadvantaged, it is currently hard to visualise whether all citizens can, will or even should be, absorbed into the latest advances we describe. In *Brain Culture: Shaping Policy Through Neuroscience*, Jessica Pykett (2015) argues:

> Learning can never be understood simply as a brain process. Rather, there are high political stakes in neuroscientific explanations of the learning process in terms of delimiting learning norms and dealing with learning differences in real places. Education is more than the aggregate sum of people learning. The shaping of conduct, behaviour and educational outcomes is a social and cultural endeavour essential to the governing of citizens in specific contexts. The brain of the learning person is not just an algorithm to be optimised. (Pykett 2015: 138)

Perhaps there will be no choice in how humans eventually become 'optimised', but then better to raise these questions now when matters are still emerging, than assume once again that we are all proceeding 'towards a pre-specified end' requiring no further debate.In *The Digitalisation of (Inter) Subjectivity: A Psy-critique of the Digital Death Drive*, De Vos suggests that when faced with events that have potential to change both the world and ourselves, we are forced to pose the '*what will* become of us?' question. However, given that humans always have the capacity to imagine themselves as something different, is the human subject ever simply what it is: 'If to be human is to be able to imagine oneself as being different then does this not signal that one never simply coincides with oneself, that one is always already other to oneself?' (De Vos 2020) With this tantalising prospect in mind, we can contemplate our digitalization as a society and as human subjects, via *subjective (self)interpellation* (De Vos 2020). To reflect therefore on how 'capitalism has finally managed to surpass both its material boundaries and the need for concrete people' enables us to imagine routes ahead that a commodification of subjectivity via digitalisation might take us (De Vos 2020).

Whether these are paths of emancipation or alienation could, therefore, depend on us continuing to 'engage explicitly with values in our decisions about the direction of education' (Biesta 2009). By taking an interdisciplinary postdigital perspective, we can maintain this debate where we are always already other to ourselves. It is a necessary dialogue because once reconfigured conditions for knowledge production, and understandings of human beings are altered beyond recognition, and endorsed via policy, it may then already be too late.

MP: Thanks, Petar for reminding us of these leading research works. I guess my emphasis has been on the concept of *technological convergence* outlined in a couple of papers focusing on the US National Science Foundation and the way in which the Foundation has funded research on the 'nano-bio-info-cogno' paradigm as developed by Bainbridge and Roco (2006). It is certainly the case that NSF believe that the 'cognosciences' (and therefore education) has lagged behind and this has motivated heavy investment in the learning sciences including biologically inspired learning systems, affect technologies, computational theory and cognitive modelling, spatial intelligence and temporal dynamics by the US National Science

Foundation (Peters 2020c). This 'deep convergence' represents a new technoscientific synergy that is the product of long-term trends of 'bioinformational capitalism' that harnesses the twin forces of information and genetic sciences that coalesce in the least mature 'cognosciences' in their application to education and research (Peters et al. 2021b). This description of convergence illustrates that it is not just one technology – digital or biological – but rather several acting together especially at the nanolevel, and the application of this model to the 'cognosciences' is being presented as the new paradigm with obvious reference to education.

While there has been much emphasis on the digitalization of the sciences and in particular, the way that digital technologies are changing how scientists work, there has been relatively little focus on the, and what I have called the 'biologizing of digital reason' (Peters 2017). I tried to develop this relation above in discussing 'organic memory' by reference to the most recent research. We are only at the very early stages of this process. Some fifteen years ago the US National Research Council set up the Committee on Frontiers at the Interface of Computing and Biology that produced the report 'Catalyzing Inquiry at the Interface of Computing and Biology' (Wooley and Lin 2005). In the Preface, John Wooley writes:

> computer scientists have pondered the significance of biology for their field. For example, computer scientists have explored the use of DNA as a substrate for new computing hardware and the use of biological approaches in solving hard computing problems. Exploration of biological computation suggests a potential for insight into the nature of and alternative processes for computation, and it also gives rise to questions about hybrid systems that achieve some kind of synergy of biological and computational systems. And there is also the fact that biological systems exhibit characteristics such as adaptability, self-healing, evolution, and learning that would be desirable in the information technologies that humans use. (Wooley and Lin 2005: vii)

There is no question of the impact of computing on biology, or consideration of a paradigm change, especially with the spectacular growth of computational biology. The impact of biology on computing is still as yet largely unfulfilled with clear potential for computer design, software, memory, intelligence and learning. The notion of a biological computer is now commonplace in the literature where DNA is conceived of as the substance for massive and growing memory and swarm intelligence and neural nets offer a different approach to algorithmic programming.

Clearly the representation of human functionality by digital computing is greatly enhanced by the introduction of biological models. For instance, researchers in nanomedicine have already begun to experiment with molecular-scale computing devices to be embedded in our bodies to monitor health and treat diseases before they progress. As a report in Scientific American puts it: 'The advantage of such computers, which would be made of biological materials, would lie in their ability to speak the biochemical language of life.' (Requarth and Wayne 2011) As one research report puts it: 'Synthetic biology aims to develop engineering-driven approaches to the programming of cellular functions that could yield transformative technologies. Synthetic gene circuits that combine DNA, protein and RNA components have demonstrated a range of functions such as bistability, oscillation, feedback and logic capabilities.' (Green et al. 2017) Molecular-scale computing devices

embedded in bodies and brains is no longer science fiction and it raises both political and ethical issues (see also Grozinger et al. 2019).

The question – does biodigitalism still fall within the ambit of biopolitics? – is important because in the field of education there has been quite a lot of discussion that follows Foucault's biopolitics (Peters 2007, 2015; Pierce 2013). It is not clear how biotechnology and biocapitalism affect Foucault's concept of biopolitics or the extent to which biodigital technologies introduce new patterns of biopower in modern life focused on the biotechnological 'utopia' of promoting and optimizing life as an aspect of biocapitalism (Yu and Liu 2009) based on the molecular reordering of the body, intelligence and nature, more generally. The intrusion of positive eugenics into education, life-saving and life-enhancing technologies and the 'genetically connected child' indicate the magnitude of ethical issues surrounding the new politics of human and particularly child biotechnology including 'designer babies'.

I found your discussion, Sarah, linking both to sustainability and to brain science very useful and suggestive of lines of inquiry. Linking the biodigital to both sustainable development and to education for sustainable development as twin aspects of a single logic. Biodigital technologies provide the basis for a new naturalism based on the growth of natural and synthetic organisms and systems, and a path-breaking science with very serious political, ethical and educational implications. The biologizing of information and computing is less obvious than the digitization of science and so far only in very early stages and yet it heralds a coming hybridization and interface that may be revolutionary.

5 Biodigitalism as Technoscience

MP, PJ, SH: The concept of postdigital condition describes reconfigurations between various technologies and humans (Jandrić et al. 2018). Early postdigital scholars focused to reconfigurations between the analog and the digital (Cascone 2000; Cormier et al. 2019); two decades later, the theme of the day is biology. As can be clearly seen from posthumanist literature (e.g. Braidotti 2019), these various reconfigurations cannot be thought of without each other. While our research efforts often focus to lower-level convergences between traditional disciplines such as biology+information or science+technology, we always need to maintain their grounding in the over-arching postdigital convergence between all sorts of disciplines and technologies produced by these disciplines and their convergences.

From the postdigital bird-eye perspective, various terms and concepts can be easily distinguished by the way of reduction to fundamental disciplines. Biotechnology refers to the convergence between the science of biology and technology, or technoscience. Biodigitalism refers to the convergence between the analog (biological) and the digital (informational). Biodigital technology refers to the convergence between the analog (biological) and the digital (informational) together with the convergence between science (biology) and technology (information). Bioeconomy expands from natural sciences to social sciences and converges biodigital

technology with economy. However, economy also results from a convergence of disciplines such as mathematics, psychology, sociology, political science and many other disciplines – and these days, most of these disciplines undergo their own biotechnological and biodigital convergences. Writing a full definition of bioeconomy would result in a very long line of fundamental disciplines and their mutual reconfigurations; depending on one's definition of a fundamental discipline, this line can always be contested and/or written differently.

As we approach complex concepts such as bioeconomy, the reductionist approach reaches its limits. These limits are ontological, because reduction to (easily contested) fundamental disciplines does not necessarily correspond to the nature of described concepts. These limits are also epistemological, because knowledge about constituents does not imply knowledge about a whole. It is with this understanding, that postdigital theory strongly advocates a postdisciplinary approach to research (Jandrić 2020).

Postdisciplinary research 'is both a rupture in our existing theories and their continuation' (Jandrić et al. 2018: 895). A typical case in the point is education, which has not in any way left behind the traditional question, 'what kind of society do we want to live in?', and its close links to hugely important aspects of our social lives such as freedom, justice and democracy. Developing the notion of precision education, Williamson (2019) points towards a convergence of education's traditional themes with psychodata, brain data and biodata; this implies that bioscience (psyche, brain, bios) needs to merge with data science (big data and algorithms) and also with social and political science (justice, democracy). Williamson (2019) finds his convergence in the concept of digital policy sociology. 'Building on existing "policy sociology" approaches combined with emerging insights from "digital sociology," digital policy sociology extends the analytical gaze to new technical actors – nonhuman software and hardware, as well as human experts, technology companies and promotional organizations.' Digital policy sociology is a good example of a postdigital research approach (because it freely combines the analog and the digital, the biological and the informational) and a postdisciplinary research method (because it is based on a high-order convergence between foundational disciplines, in which none of the foundational disciplines remain unchanged). As we proceed into the postdigital age, research approaches and methods based on high-order convergences mushroom all around us. It is through postdigital theory that these appro aches and their results can come together into a larger narrative of modernity.

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