Philosophy of Engineering and Technology

Hub Zwart

Continental Philosophy of Technoscience

OPEN ACCESS

Springer

Philosophy of Engineering and Technology

The *Philosophy of Engineering and Technology* book series provides the multifaceted and rapidly growing discipline of philosophy of technology with a central overarching and integrative platform.
Specifically it publishes edited volumes and monographs in:

- the phenomenology, anthropology and socio-politics of technology and engineering
- the emergent fields of the ontology and epistemology of artifacts, design, knowledge bases, and instrumentation
- engineering ethics and the ethics of specific technologies ranging from nuclear technologies to the converging nano-, bio-, information and cognitive technologies
- written from philosophical and practitioners' perspectives and authored by philosophers and practitioners

The series also welcomes proposals that bring these fields together or advance philosophy of engineering and technology in other integrative ways.
Proposals should include:

- A short synopsis of the work or the introduction chapter
- The proposed Table of Contents
- The CV of the lead author(s)
- If available: one sample chapter

We aim to make a first decision within 1 month of submission. In case of a positive first decision the work will be provisionally contracted: the final decision about publication will depend upon the result of the anonymous peer review of the complete manuscript. We aim to have the complete work peer-reviewed within 3 months of submission.
The series discourages the submission of manuscripts that contain reprints of previous published material and/or manuscripts that are below 150 pages/75,000 words.
For inquiries and submission of proposals authors can contact the editor-in-chief Pieter Vermaas via: p.e.vermaas@tudelft.nl, or contact one of the associate editors.

More information about this series at http://www.springer.com/series/8657

Hub Zwart

Continental Philosophy of Technoscience

Springer

Hub Zwart
Erasmus School of Philosophy
Erasmus University
Rotterdam, The Netherlands

ISSN 1879-7202 ISSN 1879-7210 (electronic)
Philosophy of Engineering and Technology
ISBN 978-3-030-84569-8 ISBN 978-3-030-84570-4 (eBook)
https://doi.org/10.1007/978-3-030-84570-4

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Contents

Chapter 1
Introduction: Coming to Terms with Technoscience

Continental Philosophy as a Research Program

In contemporary philosophy of science, continental approaches such as dialectics, phenomenology and psychoanalysis tend to be underrepresented compared to analytical and sociological ones, but the reverse is also true. Whereas continental philosophical discourse tends to focus on author studies, the urgency of coming to terms with contemporary technoscience often remains unrecognised.[1] This volume builds on the conviction that a mutual exposure and confrontation between continental philosophy and contemporary technoscience is urgent and beneficial for both.

This volume presents the oeuvres of a number of prominent continental thinkers (Hegel, Marx, Engels, Teilhard, Bachelard, Heidegger, Lacan, Althusser), but my exposition will be guided by the question how their work can help us to develop a continental philosophical approach to technoscience today. In other words, the key objective of this volume is to develop a diagnostic of the present, while special attention is given to methodological issues: *how to* practice continental philosophy of technoscience in a contemporary setting? The focus is on the *how* and on the *now*. The aim is to provide a scaffold for students and scholars (especially early stage researchers) who aim to explore the vicissitudes of technoscience against the backdrop of its societal context. Whereas in author studies the focus tends to be on *differences* between various continental positions, continental philosophy of technoscience will be presented here as an evolving *research program* to which multiple authors have contributed and continue to contribute. While being sensitive to the specificities of the positions involved, they nonetheless share a common ground.

Although the writing of this book involved a substantial amount of reading ("reading aloud", as Althusser once phrased it), it is at the same time the result of experience and practice. From the start of my scholarly activities, I have worked in

[1] Don Ihde (2000) already noticed a "lack of concern among continental philosophers concerning technoscience" (p. 59), and a focus on canonical texts by canonical authors (i.e. author studies).

H. Zwart, *Continental Philosophy of Technoscience*, Philosophy of Engineering and Technology 38, https://doi.org/10.1007/978-3-030-84570-4_1

interdisciplinary settings, practicing philosophy in close dialogue with researchers active in other fields (from biomedicine, molecular life sciences and brain research up to genomics, synthetic biology and environmental science). As a result, the views and claims presented in this volume are not solely the outcome of prototypical philosophical activities such as reading primary authors, supervising doctoral theses or engaging in discussions with philosophical colleagues at scholarly meetings and conferences. To come to terms with contemporary technoscience, proximity is crucial and I experienced the added value of presenting lectures to students in technoscientific fields, of developing research proposals together with researchers from technoscientific disciplines, and even of management activities (as director of a research institute, as principal investigator in interdisciplinary European projects and as scientific director of an interdisciplinary research program). Therefore, this text is the result of a dialectical interaction between *reading* philosophy and *practicing* it, between studying philosophy and studying technoscience.

Let me briefly outline the meaning of the key terms “continental philosophy” (the “subject” pole) and “technoscience” (the “object” pole). To start with the latter: contemporary science is referred to as “technoscience” because contemporary research is an *inherently technological* endeavour. Rather than seeing technology as “applied science”, scientific knowledge (even on a theoretical level) is a *technological praxis*, a technology-driven way of interacting with nature. The precise origin of the term “technoscience” is already a controversial issue in itself (Barnes, 2005; Hottois, 2018). The term has been attributed to Gaston Bachelard (1934/1973) but, as Gilbert Hottois (2018) rightly points out, Bachelard never literally uses the term, – although in various passages he comes very close to doing so. In *The new scientific spirit*, for instance, Bachelard argues that the rationality of contemporary experimental science is a *technical* rationality (1934/1973, p. 9), so that scientific phenomena are technical phenomena, while scientific facts are technical facts (i.e. artefacts). Similar views are presented in later publications. Modern experimental science is a “technical science”, under the sway of “technicity” (Bachelard, 1953, p. 197). Modern science is radically *reformed* and *enhanced* by the precision of modern technology, which is a *transformative* and *creative* technology, prolifically *producing* technological phenomena, so that scientific discoveries are technical discoveries (1953, p. 43) and scientific experience is a profoundly technical mode of experience. Scientific culture is a technological culture and Bachelard notices a “remarkable convergence” between molecular and computation technologies (p. 175).

Gilbert Hottois began using the term “technoscience” during the 1970s to arouse philosophers of science from their “linguistic slumber” (Hottois, 1979), but during the 1980s he became more reserved as he noticed that the term incites multiple passionate (both technophobe and technophile) reactions (Hottois, 2018) due to the “contamination” of science by big science management and global capitalism (Bensaude Vincent & Loeve, 2018). The term continued to proliferate, however, notably via the work of other influential authors such as Jean-François Lyotard (1979), Bruno Latour (1987), Donna Haraway (1997) and Don Ihde (1991). Whereas critics discard it as a buzzword, practicing scientists are reluctant to adopt it (Bensaude Vincent & Loeve, 2018). In this volume I use the term to emphasise the inherent technicity of contemporary science, while agreeing with Hottois that technoscience is a practice which is direly "in need of a conscience" (Hottois, 2018, p. 133). Technoscientific research is research in the design mode and densely populated by enabling machines, bent on reshaping the world atom by atom (Bensaude Vincent & Loeve, 2018, p. 174): knowing by intervening and making (so that *homo faber* and *homo ludens* join *homo sapiens*). Philosophy of science and philosophy of technology are converging fields, making it impossible to meaningfully address the one without addressing the other. Uncontaminated ("innocent") terms do not exist in this area, moreover. Should we revert to using *science* instead of *technoscience*, for instance, we are bound to discover that "science" is likewise a signifier that is severely tainted, disqualifying other research fields (notably in the social sciences and the humanities) as *less* or even un-scientific, while obfuscating the societal and cultural dimension of research.

The signifier "continental philosophy" is no less controversial. Although this term began its career as a pejorative label and remains difficult to define, a common profile or family likeness may nonetheless be discerned among adherents (cf. Critchley, 2001; Glendinning, 2006; Gutting, 2005; Sim, 2000). Continental authors share a certain style of thinking, a common set of intellectual challenges and ideas. Although the authors themselves (and the scholars studying their work) often highlight their differences with other (previous or contemporary) thinkers, this emphasis on dissension may obfuscate the common discursive ambiance in which they all dwell, engaged as they are in a "lively, dialectical relationship with the world" (Anderson et al., 1968).

A number of convictions shared by continental thinkers can be summarized as follows (Zwart et al., 2016). First of all, although technoscience has an enormous (and indeed, enormously disruptive) impact on the global world, for continental philosophers technoscience is not the only reliable or meaningful access to reality. There are other revealing ways of experiencing and disclosing human and natural phenomena, such as religion, various societal practices, or art. Moreover, continental thinkers see technoscience as profoundly historical, expressing and reflecting the zeitgeist of an epoch, co-evolving with cultural, political and economic developments. Also, continental philosophers see technoscience not primarily as a theory or a discourse, but first and foremost as a transformative *practice*, a form of labour, not only exploring, but also interacting with and refurbishing the world. Continental philosophers implicitly or explicitly endorse the claim that the basic objective of philosophy is to develop a diagnostic of the present, against the backdrop of a broad temporal horizon, and resulting in a prognostic of the future. Finally, they agree that we currently witness an epoch of profound disruption, of political and scientific turmoil, affecting all realms of culture, so that the current ecological and political crises reflect a metaphysical transition. The objective of philosophy is not only to assess the dynamics of this transition, but also to actively contribute to its unfolding and to address the societal challenges entailed in it. In other words, a philosophical diagnostic (as a collaborative endeavour) entails a will to intervene into the development of technoscience and its implications for society at large.

Developing a continental perspective on contemporary technoscience requires proximity, in combination with critical distance. Philosophy "of" technoscience should preferably be practiced as philosophy *in* technoscience. Philosophers should *be there*, should familiarise themselves with practical contexts of technoscientific labour. At the same time, these contexts of discovery are not assessed from an "empirical" (e.g. sociological or ethnographical) perspective, but from a philosophical angle, from an "oblique" perspective, combining dialogue with reflection (Zwart, 2017a). Speaking about philosophy *and* technoscience, the (seemingly innocent) conjunction "and" suggests a deceptive dichotomy. There is more philosophy at work *in* contemporary technoscience than scientists (and philosophers, for that matter) tend to be aware of, and our vocation is to bring this inherent philosophy to the fore, questioning it from a position of proximity, in dialogue with the practicing scientists involved. I see this as a mutual learning practice, a dialectical interaction of dialogue and reflection. The claim made in this volume is that, although continental approaches are underrepresented in mainstream philosophy of science, they entail crucial insights for understanding technoscience as it evolves on a global scale today. Notably, the authors discussed in this volume develop important perspectives concerning the *technicity* of technoscience.

Focus is inevitable and this volume notably presents (and highlights the contemporary relevance of) three continental philosophical approaches, namely dialectics (Hegel, Marx, Engels), psychoanalysis (Freud, Bachelard, Lacan), and phenomenology (Bachelard again, Heidegger and Teilhard). At the object pole, technoscience is an astonishingly broad field, from artificial intelligence via molecular biology up to astrophysics. Whereas other scholars are exploring intriguing connections between, for instance, Hegelian dialectics and cybernetics, artificial intelligence and surveillance technologies, or between phenomenology and the evolution of technological systems (Coeckelbergh, 2020; Hui 2016, 2019; Van Tuinen, 2020), the focus of this volume is on recent developments in *life sciences* research, e.g. molecular and computational biology, genomics and synthetic biology, although some attention is given to astronomy and quantum physics as well. Again, rather than on hermeneutical or exegetic quandaries, the focus is on methodological challenges: how to *practice* philosophy of technoscience today? How can dialectics, psychoanalysis and phenomenology provide methodological hints and guidance for *practicing* philosophers in various settings? The question is not, for instance, how Hegel relates to Kant, Fichte or Spinoza, or something like that, or how Heidegger (implicitly or explicitly) positions himself vis-à-vis Husserl, but rather on what we can learn from Hegel and Heidegger for understanding contemporary life sciences research. I will now briefly introduce the continental approaches presented in this volume.

Hegelian Dialectics

Modern dialectics was inaugurated by Georg Wilhelm Friedrich Hegel (1770–1831), whose thinking has been described as a "Matterhorn" to be conquered (Beiser, 2005), a "haunting phantom" (Althusser, 1962/2005), a "formidable spectre" and a "monstrous creature" who continues to speak to contemporary scholars from under the stage (Žižek, 2016/2019). While the fame of many of his critics (Russell, Popper,[2] etc.) seems rapidly declining, Hegel is more alive than ever. And yet, as Žižek phrases it, the question emerges whether it is still possible to be a Hegelian today (2012/2013). Or, as Catharine Malabou phrases the problematic in her book *The Future of Hegel*: "The philosophy of Hegel: is it a thing of the past?" (Malabou, 1996/2005, p. 1). Although many dramatic and cataclysmic events have happened since Hegel's death, which he himself could not foresee, his oeuvre continues to address us like an imposing statue. What Hegel did acknowledge (as a thinker of modernity) was the disruptive power of negativity entailed in technoscience, as a technical form of thinking which literally obliterates its object (nature), while the eventual reconciliation (the negation of the negation) is not a restoration, but a novel situation in which the disruptive factor itself (e.g. technoscience) is emphatically included. Although the scholarly literature on Hegel (in the sense of author studies) is immense, a significant part of it addresses Hegel's position vis-à-vis previous thinkers or contemporaries (Kant, Fichte, Schelling, and so forth). Although I do not deny the value of such scholarship, my reading of Hegel evidently commences from a different question: what can we learn from Hegelian dialectics concerning technoscience now? How to practice dialectics under present circumstances? I will present Hegelian dialectics as a challenging research program which continues to unfold, and as a methodology to whose further development we may contribute by *practicing* (rather than discussing) dialectics.

Hegel has been called the modern Aristotle (Ferrarin, 2001; Beiser, 2005, p. 57; Pippin, 2019, p. 301) and for good reasons. Aristotle's thinking provided a model for Hegel because it entailed a comprehensive *Gesamtwissenschaft*, a systematic encyclopaedia of all areas of inquiry. Aristotle was a universal polymath, while his philosophical encyclopaedia of knowledge was developed on the basis of a dialectical approach, providing a research agenda and conceptual lexicon for future scholars. Aristotle's key concept ἐνέργεια (being-at-work), for instance, concurs with Hegel's view of natural entities as the realisation or actualisation of an inherent program or concept. For Hegel, Aristotle was ancient philosophy's most thoroughly dialectical thinker.

The concept of an encyclopaedia of science also links Hegel with Denis Diderot (1713–1784). In his *Phenomenology of the Spirit*, Hegel refers to Diderot's novel

[2] Whereas Karl Popper (1963/2002) presents experimental research as a practice of "trial and error" and dialectics as "absurd", I will argue that experimental research is guided by a dialectical logic which moves from hypothesis via exposure and negation up to negation of the negation (i.e. the development of an integrated, comprehensive view).

Rameau's Nephew as a dialectical artwork, and to its hero as a dialectical character. In collaboration with d'Alembert, moreover, Diderot edited the famous *Encyclopédie*: a decisive philosophical event, indicating a turning-point which concurred with the most famous passage in Hegel's oeuvre: the dialectics of Master and Servant (Hegel 1807/1986). As Hegel explains, whereas the Master merely *contemplates* about nature, the Servant *interacts* with nature in a hands-on, technical and experimental manner, thereby developing a more robust understanding of how nature works. Therefore, scientific research is not only closely entangled with technological developments, but also reflects the emancipation of former "servants" from the constraints of the ideologies of their "masters". Diderot's encyclopaedia was more than a compendium. It disclosed the emerging world of practical research and research practices, introducing new intellectual heroes: the artisans, and their most important product: their contrivances, their machines. Diderot's encyclopaedia reflects how technicity was opening up a new era of research and productivity. To process all this information, an immense amount of work had to be done by Diderot and his many collaborators. They visited and deliberated with artisans in their workshops, in order to explore the undocumented realms of artisanal intellectual activity. The encyclopaedia was a critical endeavour, fostering awareness concerning the methodological challenges involved in processes of knowledge production, aiming to convince its readers of the importance of novel research areas such as experimental chemistry. The encyclopaedia represented a mundane style of thinking, studying emerging worlds, emerging practices, emerging vocabularies.

The title of Hegel's most comprehensive work (*Enzyklopädie der philosophischen Wissenschaften im Grundrisse*), on which he continued to work throughout his lifetime, entails an obvious reference to Diderot's encyclopaedia, one of the hallmarks of the Enlightenment. At the same time, Hegel's ambition to *supersede* Diderot is no less obvious. Instead of an alphabetic arrangement, Hegel produces a *systematic*, conceptual encyclopaedia, from logic via nature to spirit, from Alpha to Omega as it were, seeing the development of thinking as a spiralling process, thereby trying to achieve what Aristotle had done for ancient thinking, and Thomas Aquinas for medieval thinking (in his *Summa Theologica*), but what seemed an impossible ambition under modern conditions. Hegel's encyclopaedia entails critical dialogues concerning a spectrum of research fields (mathematics, astronomy, optics, mechanics, chemistry, biology, psychology and so forth). His encyclopaedia is a *research program*, interminable in principle, but providing an agenda, a method and a lexicon for scholars today.

For Hegel, a dialectical logic is at work not only in the historical unfolding of human thinking, but also in the dynamics of nature as such, giving rise to processes of becoming and change, via contrasting and apparently contradictory developments. The dialectical method is fundamentally in tune with nature because nature *as such* is inherently dialectical. Dialectics sees research first and foremost as a technology-driven *practice*, I will argue, focussing on the technological means of knowledge production. The dialectical approach was further developed, not only by Karl Marx (1818–1883) and Friedrich Engels (1820–1895), but also by twentieth century scientists such as J.B.S. Haldane (1892–1964) and John Desmond Bernal

(1901–1971), who argued that modern research is an inherently *dialectical* practice, optimally poised to capture the dialectical dynamics of natural processes, even on the bio-molecular level. Dialectics builds on the conviction that, notwithstanding contradictory experiences, the real is inherently rational, so that our inquiries not only allow us to come to terms with the present, but also to anticipate (and actively contribute to the unfolding of) the emerging future, so that technoscience progresses from analysis to proactivity and prediction, combining intellectual with practical ambitions. Dialectics enables reflection and self-reflection on technoscience as an evolving social praxis.

Technoscience evolves from *general* conjectures (theory), via *particular* experimental insights down to *concrete* products and outcomes. Dialectics sees technoscience as a particular form of disclosing nature. It is a critical exposition of technoscientific research practices as they appear on the scene: the path or journey of scientific consciousness, passing through a series of configurations or stations of knowledge towards more comprehensive forms of understanding. For dialectical philosophy, technoscience itself is a phenomenon, and philosophy is a dialectical "phenomenology" of technoscientific experience, discerning the basic logic that guides the journey of scientific consciousness through history. Hegelian dialectics emphasises the *negativity* of technoscience (its tendency to affect, negate and obliterate the object) and is acutely aware of the extent to which technoscience is a hyperactive, performative and transformative way of thinking. We will focus on three particular dialectical themes: (a) Hegel's view of the chemical process and the origin of life; (b) Hegel's understanding of planet Earth as a global meteorological system and (c) Hegel's view on the "end" of evolution.

Dialectical Materialism

Although strictly speaking they themselves never used the term, *dialectical materialism* refers to the work of Karl Marx and Friedrich Engels, although many other authors have contributed to this strand of dialectical thinking, up to this day. After a period of marginalisation, which coincided with the "triumph" of neo-liberalism (proclaimed as the "end of history" during the 1990s), dialectical materialism in general and the works of Marx and Engels in particular currently experience a revival, in view of the global crisis unleashed by neo-liberalism, in the form of widespread political and ecological disruption. Against this backdrop, renewed scholarly interest in dialectical materialism focusses explicitly on the disruptive metabolism of the current socio-economic system and the ecological dimension of dialectical thinking. We will focus on the work of Friedrich Engels who, as a result of the "division of labour" between Marx and Engels, developed a dialectics of technoscience and nature, initially in his correspondence with Marx, but more systematically in *Anti-Dühring* (1878/1962) and *Dialectics of Nature* (1925/1962), a collection of notes and manuscripts which he left unfinished. Dialectics, for Engels, is a method for studying the laws of development in nature, society and thought

(1878/1962). Technology enables research while researchers continuously optimise their equipment, so that scientific insight and technological prowess co-evolve. Again, the question is: how to *practice* dialectical materialism of technoscience *today*, in an era of synthetic biology, industrialised research and ecological crisis?

Special attention will be given to Louis Althusser because, in a rather polemical manner, Althusser presents a view which seems juxtaposed to the basic ambitions of this volume. Whereas this volume presents continental philosophy of technoscience as an evolving research program, Althusser posits an (allegedly insurmountable) epistemological and ideological *rupture* between Hegelian dialectics on the one hand and the work of Marx, Engels, Freud, Lacan and similar authors on the other. Since this volume presents Marx, Engels and Lacan as dialectical thinkers, and their oeuvres as radical contributions to an unfolding intellectual endeavour, Althusser's assessment seems to inhibit such a project. Therefore, we must dive rather deep into Althusser's arguments. The conclusion will be that, although Althusser's apodictic thesis concerning an insurmountable rupture ultimately proves unconvincing and self-contradictory, there is nonetheless added value in his work when it comes to developing a dialectical approach to technoscience (resulting in the negation of Althusser's negation if you like). Althusser's analyses not only build on Marx and Engels, however, but also on Freud, Bachelard and Lacan. Therefore, the chapter discussing Althusser will be preceded by an exposition of psychoanalysis of technoscience.

Psychoanalysis of Technoscience

After presenting a Freudian approach to technoscience (referring mostly to *Beyond the Pleasure Principle*, but also to a posthumously published document known as the *Entwurf*), this chapter focusses on the work of Gaston Bachelard and Jacques Lacan. I will point out how both oeuvres actually represent a convergence of psychoanalysis and dialectics.

Gaston Bachelard (1884–1962) occupies a unique position in the history of European philosophy (Aitken, 2005; Bolduc & Chazal, 2005). As a philosopher of technoscience, he emphatically acknowledges the strength, precision, productivity and reliability of technoscientific knowledge compared to every-day experience. Moreover, his epistemology closely follows technoscience as it actually evolves and is actually being practiced. Science is a "phénoménotechnique", devoted to producing, manipulating and analysing laboratory phenomena (emerging in vitro), rather than exploring lifeworld experiences (Rheinberger, 2005; Simons, 2018; Zwart, 2019). At the same time, his awareness of the revelatory force of imagination urged him to develop a poetics of science as well.[3] Whereas his noumenology (Bachelard

[3] For instance, Bachelard explains why palaeoanthropology is intrigued by caves on the basis of archetypal resonances, seeing caves not only as natural wombs or Pleistocene incubators, but also by drawing attention to the affinities between cave, cavern and cranium ("crâne" in French: Bachelard, 1948, p. 171; Zwart, 2019, p. 50).

& Reggio, 2005) aims to explain how technoscience reveals the noumenal (e.g. molecular, atomic and subatomic) dimensions of the real, his poetics attempts to disclose the noumenal (i.e. archetypal) dimension of scientific imagery (Zwart, 2019, p. 35 ff.). Concepts coined by him such as "epistemological rupture", "epistemological obstacle" and "technoscience" are still widely used, and were adopted by later authors. During recent decades, Bachelard's impact was primarily noticeable via the work of others, especially his students – Louis Althusser (discussed below) and Michel Foucault (Foucault, 1989; Gutting, 1989, p. 9; Gutting, 2005; Webb, 2005; Schmidgen, 2014; Simons, 2015; Ross, 2018) – but also via his influence on Thomas Kuhn. The latter's understanding of the history of science in terms of discontinuity and rupture in response to accumulating anomalies (Kuhn, 1962/2000) seems clearly indebted to Bachelard, although Kuhn hardly mentions him (Fragio, 2020; Gutting, 2001; Simons, 2017; Stachel, 2016). And although strictly speaking Bachelard did not coin the term "technoscience" as we have seen (Hottois 2018), he emphatically emphasises the decisive role of technicity in contemporary research (Bachelard, 1934/1973; Bachelard, 1953; Zwart, 2019, 2020d). His oeuvre still tends to be overlooked in mainstream philosophy of science. After being criticised and discarded by prominent voices such as Michel Serres, Elisabeth Stengers and Bruno Latour (Rheinberger, 2005; Simons, 2019), we currently witness a revival of interest, a reappreciation of his work (Bontems, 2019; De Boer, 2019; Kotowicz, 2018; Pravica, 2015; Simons et al., 2019; Smith, 2016; Wulz, 2010), – and for good reasons. As Bachelard explains, while the scientific revolution (during the early modern period) gave rise to what he refers to as the *scientific mindset*, the *technoscientific* revolution (during the twentieth century) resulted in a "new scientific spirit", a radically new chapter in the phenomenology of consciousness. As indicated, I will notably point out how Bachelard *actively practices* psychoanalysis and dialectics of technoscience, as complementary approaches.

Although Jacques Lacan (1901–1980) is not commonly regarded as a philosopher of technoscience, both in his *Écrits* and in his *Seminars* he developed a sophisticated psychoanalytical perspective, focussing on the connection between knowledge, power and desire. Building on Hegel's dialectic of Master and Servant, the scientific revolution (which began in the early modern period) is staged as a revolt of the menial (hands-on) Servant against the discourse of the Master (the contemplative metaphysician). During the current *technoscientific* revolution, however, this dynamic assumes a profile of its own. Researcher-servants are staged as craving subjects, intentionally focussed on (or even obsessed by) enigmatic and demanding ("impossible") objects. Technicity is put to use to isolate, manipulate and control these elusive targets of research (referred to by Bachelard as sur-objects). Thus, technicity allows researchers to become experimental experts: prolific producers of what Lacan describes as "university discourse". Eventually, the knowledge relationship is bound to falter, however, giving rise to experiences of discontent, so that technoscientific research becomes an "impossible profession", ridden by tensions and contradictions and resulting in symptoms, ranging from moral conflicts and workaholism down to fraud. In life sciences research, natural entities are literally *obliterated*, i.e. replaced by letters and barcodes. The technicity of technoscience entails a symbolisation of nature (a reduction of the phenomena of life to digital code). Notably in his Seminars, which commenced in 1953 (the year of the discovery of the molecular structure of DNA), Lacan explicitly focusses on the notion of information, whose astonishing success permeates contemporary science "with the speed of lightning". How to control the disruptive momentum of our will to control, which is evidently getting out of hand?

Heideggerian Phenomenology

For Heidegger, whose oeuvre (> 100 volumes) contains a plethora of comments on contemporary science, scientific research is inherently technical. What insights can be derived from his work for philosophers questioning technoscience today? Can Heidegger's thoughts become a source of inspiration for contemporary scholars confronted with automated sequencing machines, magnetic resonance imaging techniques and other technoscientific contrivances? While post-phenomenology is making significant contributions to understanding the social and cultural dimensions of contemporary technologies (Ihde, 2009; Rosenberger & Verbeek, 2015; Van Den Eede, 2011; Verbeek, 2005), notably from the point of view of mediation, my argument will be that a "return to Heidegger" may strengthen post-phenomenology, also in terms of methodology. For although Heidegger himself was notoriously ambivalent when it came to method, especially in his later writings, his oeuvre nonetheless contains important hints for how a philosophical questioning of technoscience could be practiced, such as: paying attention to language (to the words that we use) and taking a step backwards (towards the moment of commencement of the type of rationality at work). Thus, like Vincent Blok (2020) in his recent study, our rereading focusses on "the much-neglected theme of philosophical method", on Heidegger's attitude of questioning and confrontation. Three dimensions of contemporary technoscience will be addressed, namely: technoscientific objects (research artefacts), technoscientific sites (laboratories as unworldly environments) and technoscience as a global enterprise (big science). The focus will be on the question how Heidegger's way of thinking allows us to come to terms with "big" (global) life sciences endeavours (such as genomics and post-genomics) *today*.

From Dialectics to Phenomenology and Back

In *The Human Phenomenon* and other writings, Pierre Teilhard de Chardin (1955/2015) studies consciousness from a deep time historical and evolutionary perspective. He drastically broadens the temporal horizon of philosophical reflection by connecting deep history with the precarious present and the emerging future. Humans are presented as the moment in time when evolution becomes conscious of itself. Teilhard's panoramic oeuvre studies the emergence of consciousness from proto-consciousness (in primeval life forms) via animal consciousness and human self-consciousness up to the emerging noosphere (the global web of intelligence, information and deliberation). Whereas Hegel's phenomenology of consciousness opts for the so-called axial period ("*Achsenzeit*") as the moment of commencement, i.e. the birth of self-conscious reflection in various places on earth (e.g. China, India, the Middle East and Ancient Greece), Teilhard's approach results in a dramatic extension of the temporal horizon, informed by paleo-anthropological research. His dialectical-phenomenological view takes us from anthropogenesis (the origin of humankind) up to the current technoscientific revolution, which profoundly affects our being-in-the-world. Technoscience gives rise to the noosphere (the global web of communication and reflection) but also to neo-life (i.e. the intentional modification of the biosphere in vitro). Teilhard will be presented as a phenomenologist, but also as a profoundly dialectical thinker, who traces the path of natural and technological evolution from equilibrium via disruption and crisis up to restored equilibrium on a higher plateau of complexity and organisation. Like Hegel, Teilhard bridges phenomenology and dialectics, albeit focussing on twentieth century technoscientific developments such as genetics, molecular life sciences research and paleo-anthropology.

As indicated, labels such "dialectics" and "phenomenology" refer to evolving approaches (developed along the way) rather than strictly defined compartmentalisations. What Herbert Spiegelberg says about phenomenology, – that a "point-blank" definition is notoriously difficult to provide (Spiegelberg, 1965, p. 1) – applies to the other approaches presented in this volume as well. Nor is it possible (or desirable) to straightforwardly identify the authors discussed in this volume with *one particular* approach. Although Hegel, for instance, represents dialectics, his most famous book is actually entitled *Phenomenology* (presenting a phenomenology of the experience of consciousness as it progresses through various dialectical stages). Bachelard is initially listed as a protagonist of psychoanalysis, but he can be considered a phenomenologist as well, notably in his later works, while in Chap. 4 we will argue that, ultimately, he is a truly dialectical thinker. Something similar will be claimed concerning Lacan, whose return to Freud actually began as (and converges with) a return to Hegel. And while Marx and Engels see themselves as dialectical thinkers, building on the work of "old Hegel", Althusser posits a rupture between Hegelian and Marxist dialectics. In the case of Heidegger, the label "phenomenology" notably applies to his earlier work, while in his later writings the validity of this epithet becomes increasingly questionable. Finally, to the extent that Teilhard de Chardin (author of *The Human Phenomenon*) can be considered a phenomenologist, he is a phenomenologist in the Hegelian (dialectical) rather than in the (apodictic) Husserlian sense. In other words, while we on the one hand present and discuss a series of continental movements (dialectics, psychoanalysis, phenomenology) and on the other hand a series of prominent continental authors (from Hegel up to Teilhard), the link between both series is a dynamical (dialectical) rather than a static and compartmentalised one. More precisely: this volume presents a dialectical movement from Hegelian dialectics via dialectical materialism and psychoanalysis up to phenomenology, as a circular or *spiralling* movement, so that Teilhard's phenomenology inevitably links up with dialectics again.

Convergence

After being widely endorsed and applauded, dialectics, phenomenology and psychoanalysis have been questioned or even discarded for various reasons. Hegelian dialectics because its conceptual repertoire was seen as too abstruse and arcane to be of use for understanding concrete instances of technoscience (a verdict which will be explicitly challenged in this volume). Dialectical materialism has been discarded because of its connection with Stalinism, and Heideggerian phenomenology because of its connection with Nazism (Denker & Zaborowski, 2020). The approaches presented in this volume seem superseded by more recent strands of research, such as critical theory, post-phenomenology, Deleuzian post-structuralism, and gender studies. The basic objective of this volume is to argue that, notwithstanding the value of these recent developments, something has been lost as well, so that this volume constitutes an exercise in retrieval. Yet, rather than a dogmatic restatement of established positions, the question is *how* these continental perspectives enable us to face emerging global challenges in an era of ecological disruption and technification of nature. And I also will address the question how to respond to recent forms of criticism revolving around haunting legacies including androcentrism (or phallocentrism), egocentrism and Eurocentrism? Androcentrism builds on a questionable binary of Same and Other (Butler, 1990; Irigaray, 1985; Stoetzler, 2005), seeing philosophy and technoscience as dominated by male heroes, the work of "great men" (Zwart, 2008, 2020c), while the Eurocentric bias prevents us from developing an inclusive trans-continental perspective (Kimmerle, 2010; Tibebu, 2010). Rather than as a privilege of exceptionally gifted Master-thinkers, reflection must be seen as a deliberative and distributed endeavour (global thinking). I will point out how, after decades of specialisation and technocracy, we currently witness an episode of technoscientific convergence, between knowledge institutes and across disciplines, as technoscience aims to become more sensitive and responsive to social expectations and concerns. Through transdisciplinary collaboration and the development of interactive methodologies, technoscience aims to enable contemporary societies to address urgent global challenges. How to analyse this trend from a continental perspective? What should be the role of philosophy in such a context?[4]

[4] This volume aims to provide a synthesis, and parts of it are revised versions of previous publications: e.g. Chap. 2 (Zwart, 2017a; Zwart, 2017b), Chap. 3 (Zwart, 2020a) and Chap. 6 (Zwart, 2020b).

References

Althusser, L. (1962/2005). “Contradiction et surdetermination (notes pour un recherche),”/ “contradiction and Overdetermination: Notes for an investigation”. In *For Marx*. Verso.

Anderson, J., Kockelmans, J., & Schrag, C. (1968). Editorial. *Man and World, 1*, 3–9. https://doi.org/10.1007/BF01252589

Bachelard, G. (1934/1973). *Le nouvel esprit scientifique*. Presses universitaires de France.

Bachelard, G. (1948). *La terre et les rêveries du repos*. Corti.

Bachelard, G. (1953). *Le matérialisme rationnel*. Presses Universitaires de France.

Bachelard, G., & Reggio, D. (2005). Noumena and microphysics. *Angelaki: Journal of the theoretical humanities, 10*(2), 73–78. https://doi.org/10.1080/09697250500417225

Barnes, B. (2005). Elusive Memories of Technoscience. *Perspectives on Science, 13*(2), 142–165.

Beiser, F. (2005). *Hegel*. Routledge.

Blok, V. (2020). *Heidegger's concept of philosophical method: Innovating philosophy in the age of global warming*. Routledge.

Bolduc, J. S., & Chazal, G. (2005). The Bachelardian tradition in the philosophy of science. *Angelaki: Journal of the theoretical humanities, 10*(2), 79–87. https://doi.org/10.1080/09697250500417258

Bontems, V. (2019). *Bachelard*. Les Belles Lettres.

Butler, J. (1990). *Gender trouble: Feminism and the subversion of identity*. Routledge.

Coeckelbergh, M. (2020). *AI ethics*. MIT Press.

Critchley, S. (2001). *Continental philosophy: A very short introduction*. Oxford University Press.

De Boer, B. (2019). Gaston Bachelard's philosophy of science: Between project and practice. *Parrhesia, 31*, 154–173.

Denker, A., & Zaborowski, H. (Eds.). (2020). *Jenseits von Polemik und Apologie: Die "Schwarzen Hefte" in der Diskussion* (Heidegger-Jahrbuch 12). Karl Alber.

Fragio, A. (2020). Similarities, differences, and missed connections between Thomas S. Kuhn, Gaston Bachelard and the continental historiography of science. *Journal of History of Science and Technology, 14*(2), 94–111. https://doi.org/10.2478/host-2020-0016

Ferrarin, A. (2001). *Hegel and Aristotle*. Cambridge University Press.

Foucault, M. (1989). Introduction. In G. Canguilhem (Ed.), *The normal and the pathological*. Zone.

Glendinning, S. (2006). *The idea of continental philosophy: A philosophical chronicle*. Edinburgh University Press.

Gutting, G. (1989). *Foucault's archaeology of scientific reason: Science and history*. Cambridge University Press.

Gutting, G. (2001). *French philosophy in the twentieth century*. Cambridge University Press.

Gutting, G. (Ed.). (2005). *Continental philosophy of science*. Wiley.

Hui, Y. (2016). *The question concerning technology in China: And essay in cosmotechnics*. Urbanomic Media.

Hui, Y. (2019). *Recursivity and contingency*. Rowman & Littlefield.

Ihde, D. (2000). Technoscience and the ‘other’ continental philosophy. *Continental Philosophy Review, 33*, 59–74.

Ihde, D. (2009). *Post-phenomenology and Technoscience: The Peking University lectures*. State University of New York Press.

Irigaray, L. (1985). *Speculum of the other woman*. Cornell University Press.

Kimmerle, H. (2010). Hegels eurocentrische filosofiebegrip. In H. van Rappard & M. Leezenberg (Eds.), *Wereldfilosofie. Wijsgerig denken in verschillende culturen* (pp. 43–59). Amsterdam.

Kotowicz, Z. (2018). *Gaston Bachelard: A philosophy of the surreal*. Edinburgh University Press.

Kuhn, T. (1962/2000). *The structure of scientific revolutions*. The University of Chicago Press.

Malabou, C. (1996/2005). *The future of Hegel: Plasticity, temporality and dialectic*. Routledge.

Pippin, R. (2019). *Hegel's realm of shadows*. University of Chicago Press.

Popper, K. (1963/2002). What is dialectic? In *Conjectures and refutations: The growth of scientific knowledge* (pp. 419–451). Routledge.

Pravica, S. (2015). *Bachelards tentative Wissenschaftsphilosophie*. Passagen Verlag.
Rheinberger, H.-J. (2005). Gaston Bachelard and the notion of phenomenotechnique. *Perspectives on Science, 13*(3), 313–328.
Rosenberger, R., & Verbeek, P. P. (2015). A field guide to post-phenomenology. In R. Rosenberger & P. P. Verbeek (Eds.), *Post-phenomenological investigations: Essays on human-technology relations* (pp. 9–41). Lexington Books.
Ross, A. (2018). The errors of history. *Angelaki, 23*(2), 139–154. https://doi.org/10.1080/0969725X.2018.1451524
Schmidgen, H. (2014). The life of concepts: Georges Canguilhem and the history of science. *History and Philosophy of the Life Sciences, 36*(2), 232–253. https://doi.org/10.1007/s40656-014-0030-1
Sim, S. (Ed.). (2000). *Contemporary continental philosophy: The new scepticism*. Routledge.
Simons, M. (2015). Beyond ideology: Althusser, Foucault and French epistemology. *Pulse: A Journal of History, Sociology and Philosophy of Science, 3*, 62–77.
Simons, M. (2017). The many encounters of Thomas Kuhn and French epistemology. *Studies in History and Philosophy of Science, 61*, 41–50. https://doi.org/10.1016/j.shpsa.2017.01.004
Simons, M. (2018). The Janus head of Bachelard's *phénoménotechnique*: From purification to proliferation and Back. *European Journal for Philosophy of Science, 8*(3), 689–707.
Simons, M. (2019). Surrationalism after Bachelard: Michel Serres and *le nouveau nouvel esprit scientifique*. *Parrhesia, 31*, 60–84.
Simons, M., Rutgeerts, J., Masschelein, A., & Cortois, P. (2019). Gaston Bachelard and contemporary philosophy. *Parrhesia, 31*, 1–16.
Smith, R. (2016). *Gaston Bachelard: Philosopher of science and imagination*. SUNY.
Spiegelberg, H. (1965). *The phenomenological movement: A historical introduction, volume 1*. Nijhoff.
Stachel, J. (2016). History of science: The French connection. In A. Blum, K. Gavroglu, C. Joas, & J. Renn (Eds.), *Shifting paradigms: Thomas S. Kuhn and the history of science*. Max Planck Institute for the History of Science.
Stoetzler, M. (2005). Subject trouble: Judith Butler and dialectics. *Philosophy Social Criticism 2005, 31*(3), 343–368. https://doi.org/10.1177/0191453705051709
Tibebu, T. (2010). *Hegel and the third world: The making of eurocentrism in world history*. Syracuse University Press.
Teilhard de Chardin, P. (1955/2015). *The human phenomenon (translation: Sarah Appleton-weber)*. Sussex Academic Press.
Van Den Eede, Y. (2011). In between us: On the transparency and opacity of technological mediation. *Foundations of Science, 16*, 139–159. https://doi.org/10.1007/s10699-010-9190-y
Van Tuinen, S. (2020). Philosophy in the light of AI. *Angelaki, 25*(4), 97–109. https://doi.org/10.1080/0969725X.2020.1790838
Verbeek, P.-P. (2005). *What things do: Philosophical reflections on technology, agency and design*. Pennsylvania State University Press.
Webb, W. (2005). Microphysics. *Angelaki, 10*(2), 123–133. https://doi.org/10.1080/09697250500417332
Wulz, M. (2010). *Erkenntnisagenten: Gaston Bachelard und die Reorganisation des Wissens*. Kadmos.
Žižek, S. (2016/2019). *Disparities*. Bloomsbury.
Žižek, S. (2012/2013). *Less than nothing: Hegel and the shadow of dialectical materialism*. Verso.
Zwart, H. (2008). Understanding the human genome project: A biographical approach. *New Genetics & Society, 27*(4), 353–376.
Zwart, H. (2017a). The oblique perspective: Philosophical diagnostics of contemporary life sciences research. *Life Sciences, Society & Policy, 13*, 4. https://doi.org/10.1186/s40504-017-0047-9
Zwart, H. (2017b). From the nadir of negativity towards the cusp of reconciliation: A dialectical (Hegelian-Teilhardian) assessment of the anthropocenic challenge. *Techné: Research in Philosophy and Technology, 21*(2–3), 1–24. https://doi.org/10.5840/techne20176565

Zwart, H. (2019). *Psychoanalysis of technoscience: Symbolisation and imagination* (Series: Philosophy and psychology in dialogue). LIT Verlag.

Zwart, H. (2020a). Friedrich Engels and the technoscientific reproducibility of life: Synthetic cells as case material for practicing dialectics of science today. *Science & Society, 84*(3), 369–400.

Zwart, H. (2020b). Coming to terms with Technoscience: The Heideggerian way. *Human Studies*. https://doi.org/10.1007/s10746-020-09554-3

Zwart, H. (2020c). Revolutionary poetry and liquid crystal chemistry: Herman Gorter, Ada Prins and the interface between literature and science. *Foundations of Chemistry*. https://doi.org/10.1007/s10698-020-09381-5

Zwart, H. (2020d). Iconoclasm and imagination: Gaston Bachelard's philosophy of technoscience. *Human Studies., 43*, 61–87. https://doi.org/10.1007/s10746-019-09529-z

Zwart, H., Lemmens, P., & Landeweerd, L. (2016). Continental philosophical perspectives on life sciences and emerging technologies (editorial). *Life Sciences, Society and Policy, 12*(8). https://doi.org/10.1186/s40504-016-0041-7

Chapter 2
Dialectics of Technoscience

Genesis of Dialectics

Dialectics is a philosophical method developed by Hegel (1770–1831), but building on an intellectual tradition whose origins can be traced back to ancient Greece. Dialectics was initially practiced as an educational technique for conducting philosophical discussions. For Hegel, however, dialectical processes can be discerned in the dramatic unfolding of nature, history and human thinking as such. The first dialectical thinker, in the genuine sense of the term, according to Hegel (1971), was Heraclitus (535 – c. 475 BC), in whose "obscure" aphorisms Hegel recognises the awareness that dialectics is more than merely a technique to foster critical reflection. Heraclitus already refers to a basic logic guiding the dynamics of nature as such, to a λόγος at work in actual processes of becoming and change, giving rise to contrasting and contradictory developments ("objective dialectics", as Hegel phrases it). For dialectical thinkers, the dialectical method is fundamentally in tune with nature, because nature *as such* is inherently dialectical. Hegel considered Aristotle as ancient philosophy's most thoroughly dialectical thinker, as we have seen, while Hegel himself is regarded as a modern Aristotle (Beiser, 2005, p. 57; Pippin, 2019, p. 301).

Twenty-five centuries ago, in ancient Greece, philosophy teachers taught their students how to think. A philosophy trainer would establish a "think–shop" (φροντιστήριο), as Aristophanes (1962) once phrased it (to contrast it with the menial workshops of artisanal professions). While Heraclitus had been probing the dialectics of nature (his treatise bore the title Περὶ Φύσεως: "On nature"), Socrates and the sophists focussed on the *subject pole* of the knowledge process: on "*subjective* dialectics", as a technique for producing convincing arguments. This is how dialectics is often understood. For Hegel, however, dialectics is not merely a method for the formation of the intellect. Dialectics applies to the *object pole* ("nature") as well. The dialectical method allows us to understand the inherent dynamics of nature as such: *objective* dialectics. For Hegel (1971), Heraclitus was the first to

H. Zwart, *Continental Philosophy of Technoscience*, Philosophy of Engineering and Technology 38, https://doi.org/10.1007/978-3-030-84570-4_2

realise this, seeing dialectics as a *process*, while seeing Being as being-in-flux. The objective of dialectics is to come to terms with Being as a process of becoming, so that *being* means *being underway* towards realisation. Dialectics is not merely a method for deliberation (*Räsonieren*), but the very principle of Being as such. And Hegel's (unfinished) oeuvre must likewise be seen as "thinking in progress", as a *research program* we are invited to join and develop further.

While ancient Greek philosophy began as the awareness of Being (as the *first moment*), Heraclitus grasped Being and nature as *processes of becoming*, as we have seen, driven by conflict and contradiction. Without this dynamic of conflict, without "negation" as the *second moment*, there can be no dialectics. Heraclitus lived a solitary life, distancing himself from the daily turmoil of urban politics, solely devoted to thinking (Diogenes Laertius, 1925/1972). He taught *and lived* the divergence between thinking and daily existence, as an inevitable moment in the genesis of human consciousness. Eventually, however, this *second moment* of divergence and alienation must be sublated (superseded), and philosophy must again become committed to discerning and strengthening the inherent rationality of the real, – the *third moment*, which includes the inherent rationality of the politics of the polis: as a *concrete* realisation of the idea of a human community, but at the same time as a process of *becoming*, so that the envisioned realisation has *not yet* been completely achieved.

Dialectics conceives becoming as the unity of Being and negativity. Whereas Being is a primary position (the first moment), we experience a deficit and notice absence (the second moment). Being is marked by finitude, deficiency and deprivation. The world is not what it should be, something is missing, a tension is discerned between ideal and real, expectation and existence, ought and is. This negativity can be overcome when we acknowledge that everything is actually involved in a process of becoming, that we are *underway* to the realisation of the idea: to its actual embodiment in the physical-historical world. Realisation and reconciliation are never given, but something to strive for, requiring time and effort. The dialectical method commences with the awareness that we are *not yet* there, that we are struggling to discern a pathway towards insight and truth. Etymologically speaking, "method" (μετ' + ὁδός) literally means considering the path we have to follow, involving multiple intermediary stations and positions. The step from Being to Becoming is important, but in the case of Heraclitus becoming still remains an abstract and one-sided concept, Hegel argues (cf. De Boer, 2010). While Heraclitus persisted in negativity, what was missing was the concrete realisation of the idea, the *third* and final *moment* of concrete positivity (exemplified by the polis as a "concrete universal"). Heraclitus' thinking was not yet focussed on creating positive results (the concrete reconciliation and convergence of the ideal and the real). For Heraclitus, everything was floating and everything was fire (energy), but what was missing at this stage was the return to unity and stability at a higher level of comprehension. Heraclitus did acknowledge, however, that the process of becoming proceeds in accordance with laws (λόγος) and is intelligible in principle (Hegel, 1971).[1]

The next station on the pathway of thinking (or consciousness) was ancient atomism, represented by Empedokles, Democritus and others. Again, being is not taken for granted as something static and given (the first moment: M_1). Rather, atomism stresses the fluid, changeable and unpredictable aspects of nature (the second moment: M_2). The atomists regard nature and natural beings as composite entities, composed of minute material particles of various shapes, temporarily flocking together and dispersing again.[2] The strength of their vision, dialectically speaking, is that they discern inherent tensions in everything, seeing all entities as the temporary result of juxtaposed forces: attraction and rejection, determinism and deviation. In being in *general* (abstract being), they discern *particular* factors at work. Conflicting tensions and random swerves temporarily give rise to concrete tangible things, but it is difficult to see how high levels of organisation can be attained and maintained, especially in the case of living beings. Their weakness was that they were unable to overcome this emphasis on randomness. The atomists were unable to explain biotic nature: the emergence of *concrete* living organisms. Atomism fails to understand how *concrete* entities such as plants and animals can come into existence and maintain themselves (withstanding entropic pressures from the environment) for extended periods of time and even reproduce themselves (Schrödinger, 1944/1967). In living beings, opposition is overcome and attraction and rejection become reconciled for extended periods of time, so that inorganic chemistry becomes organic metabolism (a cycle of biochemical cycles), until they die and perish into dust (and the process starts anew).

According to Hegel, it was the achievement of Aristotle to really think through the process of Being, thereby realising the third and final moment (M_3). According to Aristotle, living beings are able to maintain themselves because they are the concrete realisation of an idea, a program (in Hegel's vocabulary: a concept, a *Begriff*). Like all dialecticians, Aristotle discerned inherent tensions in everything, especially in living beings, namely between matter and form, concept and realisation, and the living organism precisely *is* this integrated tension, this conjunction of metabolism and organisation, stability and flux, incorporation and excretion. Living beings are inorganic matter shaped by (brought to life by) the "form", the principle of life. According to Aristotle, the soul is the principle of life (Aristotle, 1986, 402a, 415b): it is the *form* or *formula* of living beings. All organisms are composite entities:

[1] This is also the morale of the famous story told by Aristotle and retold by Heidegger. When foreign visitors wanted to see the sage, they saw him warming himself at a stove. Surprised, they stood there in consternation, but he encouraged them to enter, "For here too the gods are present." They had expected something more detached, exceptional and rare: a thinker enwrapped in meditation, but his abode was the real world, the practice of everyday existence (heating rooms, preparing food), exemplified by a thing that brought people together.

[2] In his doctoral thesis, Karl Marx developed a Hegelian reading of Epicurean and Democritean atomism, focussing on the clinamen concept: the declination or swerve of the atom, as an inherent principle of change (Browning, 2000).

fusions of form and matter, resulting in the realisation or actualisation (412a) of a formula or plan (412b, 415b). Dialectically speaking, this formula or plan is the concept or notion (*Begriff*) which realises itself in concrete living entities. In terms of contemporary technoscience, the program or formula of living entities has been identified with DNA (Delbrück, 1971; Zwart, 2018).

A key concept of Aristotle's dialectics is a neologism coined by him: ἐνέργεια. This composite term is based on ἔργον ("work": ἐν–έργεια) and literally means being-at-work, being-active. The term may be translated as "actuality" (or reality) if sufficient emphasis is placed on *activity*: to *act* (on *realisation*). According to Aristotle (1993, 1050a, 21–23), being means being-at-work, a process of self-realisation, underway to stability and fulfilment (the natural end).

Another important station in the development of dialectics was late-medieval scholasticism, notably the work of Thomas Aquinas (1225–1274), where dialectics develops into a series of questions and disputations, which is clearly visible in the composition of his *Summa Theologiae*, the medieval counterpart of Hegel's *Enzyklopädie der philosophischen Wissenschaften* (Aquinas, 1922). The process begins with positing a question (*Questio*). An initial position is taken and a provisional answer is provided (*Videtur:* "It seems to be the case that…"), followed by arguments in favour of this initial position. Subsequently, however, the opposite position is presented and defended as well, giving rise to conflicting arguments (*Sed contra est*: "On the contrary it can be argued that…"). An inherent contestability or tension is discerned, giving rise to experiences of uncertainty and doubt. The original position is negated, and this is an important experience, emphasising the questionability of all provisional positions. As a dialectical thinker, however, Thomas realises that this cannot be the end result, and that the issue has to be worked through. Whereas disputation was usually an assignment for students, the master intervenes to present a third position (*Conclusio*, "I conclude…"), building on the discursive process, but in such a way that both the initial position and the opposite position are duly incorporated and addressed. The question is determined after weighing the evidence, followed by replies to the objections that emerged in the course of the process (Ad primum: "To the first, I answer that…").

This type of dialectics (scholasticism) prepared the ground for experimental thinking (the late medieval *scientia experimentalis*). In an experiment, two conditions are likewise confronted with one another, starting with a hypothesis, the initial view (*Videtur*), but also giving the floor to (and exposing preliminary insights to) rival interpretations and contradictory evidence (*Sed contra est*). The (modern) *idea* of an experiment, as a core component of technoscientific thinking, will be elaborated later, but a crucial difference between technoscientific experimentation and scholastic disputation resides in the role of technology. Experimentation is a technological practice. Both experimentation and disputation rely on standardised vocabularies (technical language), but experimental technoscience involves quantification: i.e. tools for measuring and comparing results (weighing the evidence, but now in a quantitative manner).

Besides using dialectics as a method for organising arguments, however, Thomas Aquinas discerns an inherent dialectics in being as such: a basic concordance between thinking and being, as reflected in the architecture of his *Summa*, which begins with the existence of God (the first moment), while subsequently human existence is addressed (human virtues and vices, as contrasting tendencies), until (via Christ and the sacraments), the return of Creation towards God is envisioned (the third moment). Human existence equals being underway towards fulfilment and the Christian worldview (from Paradise to Fall towards Redemption) is inherently dialectical.

Dialectics of Technoscience: First Outline

How can Hegelian dialectics allow us to come to terms with contemporary technoscience? Dialectical patterns are discerned at both sides of the knowledge production process: at the subject pole (technoscience) and at the object pole (nature). Technoscientific research practices evolve in a dialectical manner, via contradictions and refutations, allowing researchers to achieve more comprehensive levels of understanding along the way. But contemporary technoscience also reveals how natural processes themselves (from chemical reactions via metabolism and evolution up to climate change) adhere to dialectical patterns, from the organic scale down to the molecular scale and up to systemic levels. Dialectics sees technoscience first and foremost as a *practice*, as ἐνέργεια, as being–at–work. Moreover, dialectics emphasises the *technicity* of technoscience, focussing on the technological means of knowledge production, the technological contrivances through which experimental interactions (experimental dialogues) with nature unfold. Science is *technoscience* because it is an inherently technological endeavour.

This is already apparent in what is perhaps the most famous passage in Hegel's oeuvre: the dialectics of Master and Servant (Hegel, 1807/1986). For whereas the Master *contemplates* nature, the Servant *interacts* with nature in a hands-on, technical and experimental manner, thereby developing a more robust understanding of how nature works. Initially, labour is compulsory labour: a struggle for survival in the face of elimination, in the service of a lord or master, or even of the ultimate Lord and Master: transforming the world *ad majorem gloriam Dei* (Pippin, 1989). The morale of Hegel's "parable" (Pippin, 1989) is that labour requires and produces knowledge (know-how), so that history becomes a process of collective self-edification through the transformation of nature, while Masters become increasingly dependent on the skills and expertise of their Servants. For Hegel, labour is not an "application" of knowledge but an active and productive form of thinking in its own right. Therefore, dialectics not only sees scientific research as technology-driven, but also emphasises how technoscientific revolutions reflect the emancipation of former Servants from the constraints of ideological worldviews.

The three most important dialectical classics written by Hegel are the *Phenomenology of the Spirit* (*Phänomenologie des Geistes*, 1807/1986) published in 1807; the *Science of Logic* (*Wissenschaft der Logik*, 1831/1986) in two volumes, first published in 1812; and the *Encyclopaedia of the Philosophical Sciences*

(*Enzyklopädie der philosophischen Wissenschaften*, 1830/1986a, 1830/1986b, 1830/1986c) in three volumes, first published in 1817, while further elaborated versions were published in 1827 and 1830:

1807 *Phenomenology of the Spirit*
1812 *Science of Logic* ("greater logic")
Part I: Objective Logic I (Doctrine of Being)
Objective Logic II (Doctrine of Essence)
Part II: Subjective Logic
1817 *Encyclopaedia of the philosophical Sciences*
Part I: Science of Logic ("lesser logic")
Being – Essence – Concept
Part II: Philosophy of Nature (*Naturphilosophie*)
Mechanics – Physics – Organics
Part III: Philosophy of Spirit (*Philosophie des Geistes*)
Subjective – Objective – Absolute Spirit

Hegel's conception of dialectics was further expanded by subsequent authors, notably Karl Marx (1818–1883) and Friedrich Engels (1820–1895), but also by twentieth-century scientists such as J.B.S. Haldane (1892–1964), Joseph Needham (1900–1995) and John Desmond Bernal (1901–1971).

Dialectics starts from the conviction that a dynamical λόγος (a logical pattern of development) can be discerned in nature and human history, including the history of human thinking and of technoscientific research. In contrast with historians or sociologists of science, Hegel does not look upon history as an empirical process, but as the progressive self-realisation of a concept. The history of modern chemistry, for instance, is the history of the unfolding of the idea of chemistry as a science, while the history of the university is the history of the unfolding (in various settings and circumstances) of the idea of a university. And the question always is whether a particular chemical practice or a particular academic practice lives up to (is in agreement with) its idea. Everything strives to realise its formative idea, and a university (say, Erasmus University Rotterdam) is an evolving concretisation of this idea, an institutionalised organisation driven by the collective strive for mutual recognition (Pippin, 1989, p. 170), via citations, rankings or otherwise. Historical inquiry into processes of realisation become an integral part of dialectical epistemology (Beiser, 2005, p. 30).

In laboratories around the globe, dialectics is at work both at the subject pole and at the object pole of the knowledge production process. A dialectical dynamic can be discerned, not only in natural processes assessed by technoscience, but also in the ways in which technoscientific concepts and contrivances develop over time and research is institutionalised and organised. Technoscience is itself a dialectical endeavour, studying the dialectics of nature in a dialectical fashion. A technoscientific experiment is a dialectical design, starting with a *general* hypothesis (the first moment) which is exposed to (confronted with) a sample of reality, under *particular* (controlled) conditions, technologically determined. Although first results often seem disappointing, this actually is an edifying experience, urging the researchers involved to question and overcome their initial biases and misconceptions, resulting in a *concrete* model design (a “paradigm” if you like). In the long run, experimental research aims to confirm that nature is intelligible (that the real is rational) and that experimental designs may be optimised to such an extent that they become replicable by others, even by sceptics and critics, until the next trauma occurs, in the form of a replication crisis, for instance, when empirical data suddenly refuse to live up to (or correspond with) theoretical expectations. But it is only via such laborious processes of working-through that real knowledge can be gained.

Dialectics builds on the conviction that, notwithstanding contradictory experiences, the real is inherently rational, so that our inquiries not only allow us to come to terms with the present, but also to anticipate (and actively contribute to the unfolding of) the emerging future, so that technoscience progresses from analysis and assessment to prediction and pro-activity. Science evolves from *general* conjectures (theory) via *particular* insights (validated by experiments) towards *concrete* outcomes, combining intellectual with practical ambitions: enabling reflection and self-reflection, but also enhancing science as a praxis (by providing informed options for action). Technology facilitates research, while researchers optimise their equipment, so that scientific insight (knowledge) and technological prowess (power) co-evolve.

The Oblique Perspective

An optimal introduction to dialectics of technoscience is provided by Hegel’s own introduction (*Einführung*) to his first major work, the *Phenomenology of the Spirit* (1807/1986). Phenomenology, in the Hegelian sense, is the science (*Wissenschaft*) of scientific experience. Whereas natural sciences study natural phenomena, the aim of philosophy is: coming to terms with *scientific knowledge itself* as a phenomenon. Natural sciences are experiential sciences, and the paradigm of technoscientific experience is the experiment. In French, the term *expérience* captures both meanings and may be translated as “experience”, but also as “experiment”. Science analyses experiences obtained under specific conditions, concerning replicable phenomena. The experimental protocol points out exactly how particular phenomena can be produced; how particular experiences can be obtained. Philosophical phenomenology studies experimental practice as a phenomenon, focussing on the grounding idea that fuels it, such as the grounding conviction that natural phenomena can be grasped through systematic manipulation. If we study experimental science from a phenomenological perspective, we notice that a triadic dialectical pattern is at work here. If the grounding conviction, embodied in a particular experimental design, is considered as the first moment (M_1), this initially gives rise to experiences of frustration, disappointment and doubt: the second moment (M_2), referred to by Hegel as the moment of negation. Preliminary results suggest that the primary conviction is refuted by the refusal of the facts to confirm our expectations.

This experience is inevitable and necessary, however, urging us to improve our design, method and contrivances. Drastic interventions give rise to a higher level of practical performance, where phenomena may confirm our predictions after all (the third moment, the *negation of the negation*: M_3). The grounding conviction that experimental research is a reliable source of evidence is saved, until additional complications and anomalies accumulate again. We have to expose ourselves to this laborious and frustrating experience. Eventually, the experiential route is the only path towards reliable knowledge. And phenomenology follows scientific consciousness on its laborious and winding path in the direction of validated insight. It is only by following this path that scientific consciousness awakes from its slumber and discerns the deficient nature of accepted views. It is only by putting these insights to the test that we become aware of our knowledge deficits. It is only in this manner that we understand that, by relying on accepted and self-serving forms of knowledge, we are neglecting our intellectual vocation.

Technoscience is driven by a *cupido sciendi*, a desire to know (Zwart, 2019a). At a certain point, consciousness begins to question established *ways of knowing*. How reliable is our knowledge? How can we ascertain that our knowledge is adequate? The focus of attention shifts from knowledge as such to the process through which knowledge is produced. Philosophy is precisely the science which represents this shift. While the natural sciences are focussed on knowing the object, philosophy aims to understand *knowing as such*: how are scientific objects known by science? Philosophy is a critical assessment of the ways in which science allows reality to appear, an exposition of scientific research practices as they appear on the scene: the journey of scientific consciousness towards optimised knowledge: passing through various configurations or stations of knowledge towards more comprehensive forms of understanding. For philosophy, science itself is a phenomenon, and philosophy is a dialectical "phenomenology" of scientific experience, discerning the basic logic that guides the development of scientific consciousness.

Initially, this focus on knowledge as such (on the processes of knowledge production) results in discontent, in scepticism and despair. How to prevent knowledge from going astray? How to convince ourselves that our research practices are valid? As Hegel argues, scepticism may end in paralysis, and the fear of erring itself may become an error. Scepticism must be overcome, by incorporating it in our methodologies. Our reliance on existing knowledge practices seems biased and naïve (M_1). The reliability of established practices is questioned, negated (M_2), but, as Hegel phrases it, there is something positive in this moment of negativity. Instead of completely annihilating our results, we rather understand that we are *not yet* there. The knowledge deficit summons us to enhance the knowledge process. Instead of allowing scepticism to become a paralysing trap, it should be "taken up", as an inherent aspect of our methodology: the negation of the negation (M_3), where paralysis gives way to productivity. Dialectics studies this triadic unfolding, from unquestioned conceptions via scepticism and despair up to validated knowledge. Scepticism (negativity) is important, because it reveals the questionability of available conceptions, but it should not become a pretext to keep aloof as a "beautiful soul". We must learn from our experiences.

If we look at scientific research as a phenomenon, what strikes us is the resolve of science not to rely on the authority of others (Hegel, 1807/1986, p. 73): the desire to produce knowledge yourself and to accept only your own products as valid and convincing, even if this initially entails a dramatic *loss* of knowledge (sacrificing and negating accepted conceptions and inherited worldviews). Science is the zealous resolve to follow this process to completion, moreover, notwithstanding multiple experiences of doubt and despair. Science, Hegel argues, is an unhalting process which finds no satisfaction in intermediary stations of knowledge (p. 74) and we should acknowledge this unrest of science which unceasingly disturbs and spoils its own satisfaction: the relentless drive to take the knowledge process further. This is what invokes both fascination and uneasiness (*Besorgnis, Misstrauen*, p. 69): the Faustian dynamic of scientific practice which often eliminates more than it creates.

By analysing the knowledge process rather than the objects (microbes, organisms, galaxies, Majorana fermions, etc.), philosophy opts for a sideways or oblique perspective: a signature feature of dialectics (Zwart, 2017a). Thomas Aquinas (1922) already argued that, whereas human understanding is initially directed towards external reality (the *intentio recta*), critical reflection on human understanding (philosophy) requires a change of perspective (an *intentio obliqua*). A dialectics of contemporary technoscience is a critical but engaged assessment of the way in which technoscience (as a particular instantiation of logos) allows reality to emerge. Adopting an oblique perspective means: raising questions that are usually not raised by practicing scientists themselves, such as: What is nature? What is life? What is truth? What is science? We may use our philosophical hammers and stethoscopes to develop a diagnostic of the technoscientific present, reading technoscientific papers with a philosophical eye and listening to technoscientific deliberations with a philosophical ear. Rather than in viruses, microbes, Higgs bosons or black holes, philosophers will be interested in the ways such entities are envisioned and addressed. Our intentionality is neither focussed exclusively on the object pole (as scientists tend to do), nor exclusively on the subject pole (as sociologists and ethnographers of science tend to do), but rather on the interaction between subject and object, on the mutual interpenetration of both poles, exploring how scientific technicity allows nature to appear in a certain manner and on the inherent ontological convictions that materialise in specific scientific contrivances and the phenomena they disclose, – technoscientific tools as mediators between the subject and the object pole of the knowledge process (Pippin, 1989, p. 245). In dialectics, the axis of attention is tilted, urging us to take a quarter turn, following technoscientific debates with *evenly-posed attention*, until at a certain point in technoscientific discourse something questionable emerges, which triggers our attention and entices us to adopt a more critical, active and questioning stance.

The argument developed so far provides an affirmative response to a question raised by Slavoj Žižek: "Is it still possible to be a Hegelian today?" (Žižek, 2012/2013, p. 193). "Is there a place for modern science in Hegel? Is not the explosive growth of the natural sciences from the eighteenth century onwards simply beyond the scope of Hegel's thought?" (Idem, p. 458). Frederick Beiser (2005) raises a similar question, albeit in slightly different terms: Why read Hegel today?

Although I do not agree with his experience that Hegel's language is so impenetrable and obscure that reading him is "the intellectual equivalent of chewing gravel" (p. 1), – for I have always genuinely enjoyed reading Hegel – the question as such is a valid one. A Hegelian approach to technoscience, I will argue, is not only possible, but more urgent and relevant that ever. Dialectics entices us to study technoscience as an active ("*tätig*"), performative and transformative form of thinking, while Hegel's ideal of restoring the unity of ourselves with nature seems remarkably timely. According to Beiser, we *either* treat Hegel as a contemporary, focussing on what seems relevant to contemporary concerns, *or* we opt for a hermeneutical "author studies" stance, seeing Hegel as a historical figure. Faced with this dilemma, Beiser himself opts for "the older hermeneutical method" (p. 5). My "third" option overcomes both anachronism and antiquarianism, however, focussing on Hegel's dialectical *method*, reading Hegel *from within*, reinvigorating his legacy by incorporating both aspects. For developing a dialectical perspective on technoscience, a careful primary reading is required. The methodological *Geist*, the dialectical ἐνέργεια at work in his writings is what we are after, a way of practicing philosophy that merits to be taken up and developed further. The antagonism "hermeneutics" versus "application" is misleading. Aristotle's concept ἐνέργεια (*act*-ivity, being-at-work) implies we can only understand Hegelian dialectics by actually *practicing* it, combining theory with praxis, reading with actualisation. How to practice dialectics *in* technoscience today, how to enact a dialectical approach to contemporary technoscience? By using our own philosophical experiences (as practicing philosophers) as source material and by participating in technoscientific projects as concrete dialectical "case studies".

The Inherent Negativity of Technoscience

For Hegel, an important dialectical feature of nature is polarity. In order to study something, its opposite must be considered as well. Initially, we know what health is, for instance (M_1): it is the natural way of being-in-the-world, but to really understand health, we need to study disease as well, as the negative of health (M_2). By studying this polarity, health will no longer be taken for granted. Rather, because of this experience of illness, we understand health as a systemic outcome and as a *process* (M_3).

Besides polarity, negativity may take multiple other forms as well. Paradoxically perhaps, research always requires absence. Research begins with elimination, with the creation of a clearing or a void. Take Newton's optical experiments, conducted during the "wonder year" 1666. In order to study light, Newton created its opposite, darkness: a dark room, a *camera obscura*, a darkened room. Here, he made a little hole in the wall, an artificial orifice, a pupil so to speak, to allow a minimum of light (a small beam of sunlight) to enter the darkness, small enough to be manageable and modifiable with the help of a prism.[3] He thus created an artificial eye, with a pupil (the hole), a lens (the prism) and a retina. The prism diffracted the beam into a spectrum, projected upon a screen. Light requires darkness to illuminate, to become visible and modifiable (with the help of a prism and a screen). You cannot see, let alone manipulate light unless you create darkness first. Optics begins with the *negation* of light, which may seem paradoxical but is quite inevitable, dialectically speaking, because we analyse something by allowed it to stand out against the opposite extreme:

Light as a general and natural phenomenon (M_1) → Otherness (M_2): polarity and diffraction, creating darkness to study diffracting beams of light → (M_3) Understanding white light as a composite unity, a converging spectrum of colours.

Human consciousness itself is this dark ambiance, this night where something flares up and disappear again. We see this night, Hegel argues in his Jena lectures, when we look a human being in the eye, looking into this night, the night of the world. Consciousness is night, the eye is a night, the laboratory is a night (mimicking the eye) and the computer is a night, with a screen on which visible entities suddenly appear. The same contrasting technique is applied by playwrights, where spotlights reveal the actions of the protagonist against a backdrop of darkness: drama as a mis-en-scène, a staged experiment.

Instead of light, we may also use life as an example. Why is life studied *in vitro*, in a test-tube? What *is* a test-tube? At first glance, a test-tube may seem a trivial, quasi-self-evident laboratory item, producible on a massive scale, but on closer inspection, it is actually a rather remarkable thing. It is something completely transparent and empty, a thing which comes close to (which verges on) nothingness: an artificial void, an object without properties, a minimal object, a pure container. All properties have been obliterated and stripped away, until all that remains is a translucent glass membrane. This empty test-tube is waiting for something, standing out towards something, designed to become the recipient of an enigmatic and highly valuable "something" which is not yet there and whose ontological status seems highly uncertain: on the boundary between living and non-living, between natural and artificial. The thing which finally comes to fill the tube is likely to be something contentious, a thing which calls for a deliberation, a critical assessment, a review. Will this thing, this something (this novelty) pass the test? The empty tube inevitably refers to something which one day may come to occupy (and thereby *negate*) its emptiness, as the enigmatic object of technoscientific desire: *the negation of the negation*. In short, the test-tube embodies the three stages of the dialectical unfolding. In order to understand natural life in general as it presents itself to us (the first moment: M_1), technoscience creates a clearing, an empty space, where (almost) everything is negated and eliminated (M_2): a particular ambiance consisting of

[3] Cf. the question raised by the nuns' choir in *The Sound of Music*: "How do you hold a moonbeam in your hand?". Techno-scientifically speaking, Newton had already solved the challenge.

virtually nothing, but therefore (almost) completely under our control. And it is precisely here that something concrete will occur or emerge. Components may be isolated, but a test-tube may also be employed to bring them together again, to reconcile them (Συλλογισμός), thereby concluding a process. If this comes about, the entity *in vitro* will be the concrete culmination and convergence of previous partial insights, acquired through test-tube research, but now reassembled in a concrete singular entity, a concrete universal, containable in a tube (M_3).

The test-tube (as a materialisation of nothingness) exemplifies the dynamics of technoscience as such. To study a living entity (M_1), laboratory research commences with the creation of a clearing, an artificial ambiance (M_2). To study it, life first of all has to be negated and taken apart. Technoscience creates an abiotic, gnotobiotic ("clean") environment where life has been effectively obliterated: the laboratory, the sterilised test-tube, where real (natural) life is kept at bay. Here, isolated instances of life are deliberately introduced, particular (partial) biotic objects, single cell organisms or bacteriophages, for instance.[4] They become fully modifiable in an Umwelt which actually is the negation of a natural Umwelt, so that the object (the entity under study) cannot be contaminated by real life. The trapped entity becomes life in general (*das Allgemeine*: A), life as such. The starting point is a model organism, which serves as a living test-tube, stripped of all particularities, representing life in general. Subsequently, particular factors are isolated and brought to the fore (*das Besondere*: B): environmental factors, or particular genes which are knocked-out or added. And finally, a concrete exemplification or realisation of an idea (a synthetic compound for instance) can be produced (*Einzelheit*: E). A laboratory is a particular kind of clearing where life can be optimally controlled, against an abiotic backdrop of negativity. Where the natural is eliminated, neo-life can emerge.

(M_1) the model organism, representing life in general → (M_2) analysis in vitro, revealing particular genetic or environmental, genotypical or phenotypical factors → (M_3) re-synthesis, neo-life, as the concrete realisation of the laboratory view of life.

Negativity (as a second moment) is an inherent feature of inquiry, pushed to its extreme by contemporary technoscience. Technoscience represents what Karin de Boer refers to as "the tremendous sway of negativity" at work in modern thinking (De Boer, 2010, p. 2). Dialectically speaking, this is quite inevitable.

Suppose that technoscience aims to understand the functioning of a tree for instance. Initially, during the first moment (M_1), we discern the tree as it presents itself to us, as a natural phenomenon: a gestalt in a natural Umwelt, clad in natural daylight. Once this tree enters a laboratory setting, however, negativity sets in. To understand a living being, it has to be taken apart. Technoscience will never be satisfied until this process is pushed to its extreme. During this process (analysis *in vitro*) we discover that the tree as such basically consists of cellulose, a noumenal compound whose chemical composition can be represented symbolically ($C_6H_{10}O_5$).

[4] "[Der Mensch] fixiert Einzelnes, hebt es heraus, nimmt es als ein … Abstraktes und Allgemeines" (Hegel, 1830/1986a, § 24 Z, p. 83).

The living tree is obliterated, replaced by chemical symbols (M_2).[5] The tree as it initially appears to us (the living phenomenon) is reduced to its basic noumenal components, so that we conclude that the tree (essentially) = $C_6H_{10}O_5$.

$$M_1\left(\text{the visible tree as a whole}\right) \rightarrow M_2 \left(\text{analysis: a tree} = C_6H_{10}O_5\right)$$

The more technoscience is in control, the more the naturalness of living beings will vanish, so that their richness becomes impoverished (cf. Posch, 2011, p. 189). Dialectically speaking, this is both inevitable and rational, but it is also a disquieting experience. We have evidently lost something underway: the living organism as a whole. How to retrieve this original, organic, organismal unity?

The dialectical process is incomplete and this is where the third moment (M_3) sets in. Somehow, the negativity of technoscience itself has to be *negated* (the negation of the negation) via a concrete countervailing intervention. This return (*Zurückführung*) from splitting (*Entzweiung*) to wholeness (*Einigkeit*) is not a return to the original, purely natural situation, but brought about by a conscious, technoscientific intervention (Hegel, 1830/1986a, § 24 Z 3, p. 88–89). The splitting (*Entzweiung*, *Zerlegung*) of natural entities into their constitutive components is a *result* of human labour, but also *overcome* (sublated) by human labour (p. 89), namely by recombining these components into a synthetic whole (the concrete product).

Technoscientific research fields such as cell biology or biochemistry are about knowing the chemical composition of organisms, and dialectics aims to understand what is gained and lost during this process of knowing, for dialectics (as we have seen) is *knowing about knowing* (understanding understanding). Technoscience gives rise to particular experiences, while laboratories and test-tubes are particular kinds of clearings, allowing life or nature to emerge in a certain manner (stripped of its abundance). The laboratory is a particular ambiance where a particular praxis unfolds and dialectics allows us to discern the basic *experiences* of loss and progress (in the dialectical sense) entailed in biochemistry or molecular biology, as stations on the pathway towards comprehensive knowledge.

Outline of a Methodology

Dialectics entails a triadic pattern of positions or *moments*. An initial situation of relative stability (M_1) is challenged and disrupted by experiences of contradiction, negativity and crisis (M_2), until a new era of stability is regained, but now on a higher level of complexity and comprehension (M_3): $M_1 \rightarrow M_2 \rightarrow M_3$.

---

[5] "Das Denken übt eine negative Tätigkeit aus; der wahrgenommene Stoff … bleibt nicht in seiner ersten empirischen Gestalt. Es wird der innere Gehalt des Wahrgenommenen mit Entfernung und Negation der Schale herausgehoben (1830/1986a, § 50, p. 132)."

A life form, say: a plant, is contained in its seed as the incapsulated concept or program of the plant to be (M_1). The aim of the seed is not to stay what it is, however, but to come to the fore and expand, even if this entails facing multiple challenges and instances of resistance (i.e. moments of *negativity*: M_2). Plant life *requires* these challenges to thrive, and it is only by overcoming them that the initial seed may develop into a concrete, full-fledged organism, and become what it basically is (M_3). Whereas the environment initially seems hostile to all newcomers (exposing budding life forms to multiple threats), the plant eventually *needs* these triggers from the environment to flourish, needs to find (or create) a viable place in this demanding ambiance (a process known as individuation: $\rightarrow M_3$).

The first moment is never purely empirical, but always already framed by preconceptions. Subsequently, a sense of discontent points to a conceptual deficit. And this provides the impulse to carry the process further. The preconceptions are actively questioned. This second moment (the negation) is a crucial step forward. Besides a negative result (eliminating misconceptions), there is a positive result as well, because it may become the turning point towards genuine understanding: the negative of the negative, and therefore something positive, superseding initial contradictions (Hegel, 1831/1986, p. 563).

Hegel uses the solar system as an example. Initially the sun seems something empirical, something which can be pointed at, but this "pointing at" is always already incorporated in a conceptual context (e.g. the geocentric worldview). Via doubt and scepticism ("doubt that the sun doth move", Hamlet, Act 2, scene 2), we arrive at a more developed form of understanding, i.e. the awareness that the sun can only be fully understood (in its concrete existence, true to its concept) in relationship with other corporeal entities, e.g. planets revolving in elliptic orbits, and distant stars, for the sun is also a star, while stars are suns, consisting of radiating plasma. Something is lost (the geocentric, anthropocentric universe), but a more comprehensive understanding of astronomy is gained. Thus, the sun becomes something systemic, our centre of gravity, keeping planet Earth in its orbit, as well as being our source of energy and light.

A dialectical pattern can be discerned in processes of becoming, not only in nature, also in our scientific efforts to *understand* how nature works. Initially, a natural thing (say, a stone) may strike us as a continuous unity or whole (M_1). Until we realise that discontinuity and punctuality exist in nature as well (Hegel, 1971) and that the stone is actually a porous entity, composed of matter, but also full of emptiness as it were. Continuity and wholeness are "negated" by the insight that all matter consists of molecules distributed through space (M_2). Eventually, however, we will realise that a stone is actually both, a combination of something solid and massive on the macro-level and something porous on the molecular level (M_3).

A similar pattern can be discerned in the way in which we humans relate to nature. Initially, we must have been in awe of nature, and nature must have invoked in us a sense of admiration and respect (M_1). Nature was "observed" by us, in the original sense of the Latin verb *observare*, which means: to *heed*, to *serve* and to *respect* nature. Inspired by this devoted interest in nature, however, human observation became increasingly acute and precise, with the help of precision instruments to aid our natural sense organs (such as telescopes etc.). And this inevitably resulted in a traumatic experience (M_2), namely that nature is not as perfect as was initially expected. Anomalies and inconsistencies accumulated, and respect for (the perfection of) nature was increasingly challenged and subverted by a growing inability to actually confirm the initial view. This experience (of tension, contradiction or frustration; the second moment: M_2) forced scholars to realise that, apparently, their starting point was one-sided and naïve. The initial position was "negated". In terms of dialectical logic, this moment of contradiction and negation is inevitable and necessary, entailing an important *truth*. Fascination and actual discovery must be reconciled again, but now on a higher level of comprehension, via a more elaborate understanding: a "negation of the negation", a position which *takes up*, but at the same time overcomes the unsettling, disturbing truth of negativity. On this higher level (M_3), we are again humbled and awed by the immensity and complexity of nature, but now informed by a more detailed and sophisticated understanding, engendered by experiences resulting from the use of advanced and sophisticated technologies (as means of knowledge production). Dialectics not only aims to understand, but also to optimise this process of understanding nature, which relies on developing techniques that allow us to systematically assemble and process huge amounts of high precision information.

This triadic pattern can also be captured in slightly different terms. Initially (M_1), being and nature are experienced in a rather *general* and abstract manner. In ancient Greece, for instance, philosophers aspired to come to terms with nature *as such*. They spoke about life, nature and human existence on a general level, they aspired to capture *das Allgemeine* (A) in thoughts. This type of reflection was non-technical: it did not rely on, but rather haughtily looked down upon the practical experiences of artisans and farmers (in interaction with real nature). With regard to living beings, for instance, philosophy tried to develop a general conception of life *as such*. The next step (M_2) is the awareness that *particular* forces or dimensions can be discerned in life and nature, and that these forces or dimensions are often in contradiction or opposition with one another, so that the focus of attention shifts towards these seemingly incompatible components (in Hegelian terms: *das Besondere*, B). Quite often, this means: highlighting one particular dimension at the expense of others. For instance: highlighting "nature" (e.g. heredity) while obfuscating "nurture" (environmental factors). By taking a radical stance, the contradiction is *pushed to its extreme*, moreover. With regard to living beings, this stage typically generates radical claims, such as the claim that living beings *are* (the product of) their inherited *nature* (heredity), or that living beings *are* (the product of) their environment, or (in the case of human beings) that humans basically *are* their brains (that the essence of human nature *is* the human brain), etc. Usually, such claims rely on the employment of *particular techniques*. Eventually, however, this will inevitably result in the more comprehensive awareness that *concrete* living beings are actually the product of the *interaction* between seemingly contradictory forces and components. During the third moment (M_3), the focus of attention shifts towards *concrete* living entities (in Hegel's terminology: *Einzelheit*, E). These are now regarded as products of interaction, between genomes and environments, between heredity and adaptation, between nature and nurture, etc. Rather than on *one particular* technique, research now employs a broad range of technical contrivances so as to study a particular entity from multiple perspectives. Thus, the logic of dialectics (the basic pattern) can be captured by two formula.

$$M_1 \rightarrow M_2 \rightarrow M_3$$
$$A \rightarrow B \rightarrow E$$

These three moments are often referred to as “thesis”, “anti-thesis” and “synthesis”, but these are not the terms Hegel himself actually used. Hegel often refers to the first position with the help of terms such as *zunächst* (“initially”), abstract or *Anfang* (“commencement”). The second moment is the moment of negativity, of diremption or *Zerlegung* (“taking apart”), using specific tools to open up the opacity and interiority of natural entities. While thinking (questioning the real) itself already is a negating activity (Pippin, 2019, p. 139), this becomes quite evident in experimental practice. The third moment is the *negation of the negation*: the *Aufhebung* (“sublation”, supersession) of the second moment, which is literally “taken up”, that is: incorporated and encompassed in a comprehensive view (at a higher level of comprehension), envisioning the concrete whole. For instance, after reducing a living organism (a tree: M_1) to its basic molecular components (cellulose, etc.: M_2), we eventually encounter the cell as a *concrete, integrated whole* (M_3), the *concrete universal* of life. To reach this third position, however, it is inevitable to pass through these moments of negativity. We cannot reach it directly or intuitively. Real insight and knowledge are the products of experience and hard work, with the help of sophisticated, tested, validated and calibrated tools for processing allegedly contradictory forms of information.

This allows us to discern the inherent dynamics at work in nature, technoscience and human existence. Dialectics is not a general (abstract) schema that can simply be “applied”. Rather, via exposure to concrete phenomena, to particular (at times unsettling) experiences, we become sufficiently experienced to develop a comprehensive view. Dialectics is a praxis, i.e. a form of philosophy which can only thrive by being put to practice, by being *practiced*. The *general* idea operates in a *particular* context, resulting in a *concrete* outcome, e.g. a case study which allows us to bring together (συλλογίζεσθαι, “take into account”) seemingly erratic and dispersed developments into a concrete whole.

The use of dialectics is timely in view of the challenges we are facing. Against the backdrop of a global political and environmental crisis, we witness a conceptual gigantomachia – a tectonic collision concerning our “philosophemes”: our answers to questions such as “What is being?”, “What is truth?”, “What is nature?”, “What is life?”. It is precisely here that dialectics has a role to play. The basic convictions guiding scientific research are *acted out* in a global scene, and dialectics not only aims to assess the current crisis, but also to contribute to the imminent turn (the effort to supersede the unfolding crisis). Philosophical reflection should not be conducted from an outsider’s position, maintaining a distance between philosophy and the other faculties, as Kant (1798/2005) proposed. Philosophy should function as an inherent component of the technoscientific endeavour as such. Its guiding concepts are active in a performative manner, they are "alive" (Pippin, 2019, p. 255). The question whether we should be guardians of a philosophical past or critics of the technoscientific present is a misleading dichotomy. A philosophical assessment of contemporary technoscience is only possible against the backdrop of an extended temporal horizon and requires a solid embedding in the history of philosophical thinking. Our vocation is to revivify and *rethink* this tradition, exposing it to contemporary developments in global technoscience and their planetary impact.

As indicated, philosophical assessment of contemporary technoscience requires proximity: philosophy practiced as philosophy *in* science. Philosophers should *be there*, should familiarise themselves with emerging contexts of global technoscientific discovery, from an "oblique" dialectical perspective, focussing on the basic philosophemes at work in technoscience. As Hegel argues, phrasings such as "philosophy *and* science" may easily misguide us, as there is more philosophy at work *in* contemporary technoscience than we tend to be aware of, and the vocation of dialectics is to bring this inherent philosophy (these latent philosophemes) to the fore, so as to become conscious of them and question them, from a position of close proximity, in dialogue with the practicing scientists involved. Scientists and philosophers will both benefit from this mutual exposure, this dialectical interpenetration of praxis and reflection.[6]

Another misguiding dichotomy suggested by the word "and" is the phrase "science and society". Here again, we are actually facing mutual interpenetration (Levins & Lewontin, 1985, p. 5). Science and society mutually pervade one another. In contemporary social environments, technoscience is omnipresent and pervasive, while socio-economic and socio-cultural realities are emphatically present in technoscience as well. The Anthropocene concept reflects this mutual interpenetration of contemporary technoscience and the global lifeworld (Lemmens & Hui, 2017). Let this suffice as a first introduction, based predominantly on Hegel's *Phenomenology*. In the next sections, this view on dialectics will be further elaborated, using the first two volumes of Hegel's *Encyclopaedia* (his shorter *Logic* and his *Philosophy of nature*) as our guide.

Hegel's *Logic*: The Interaction Between Philosophy (as a Science) and Science

A comprehensive introduction into the logic of dialectics is provided by Hegel's so-called "shorter logic" or "encyclopaedia logic", i.e. the first part of the *Encyclopaedia of the Philosophical Sciences*. Here, Hegel argues that philosophy is

[6] The design of this chapter reflects this: moving from rereading Hegel as our primary source, via particular confrontations (with chemistry, genomics, synthetic biology, etc. as "other"), resulting in a concrete methodology as product.

science, i.e. laborious, methodological work, conducted in close collaboration with the natural sciences ("Hand in Hand mit den Wissenschaften"; *Vorrede*, 1830/1986a, p. 15). Until the eighteenth century, Hegel points out, the science–philosophy divide as we know it today was inexistent. Philosophy entailed an oblique, reflective perspective, albeit on the basis of active involvement. Philosophers (from Cusanus up to Leibniz) made decisive scientific contributions. If we consider this as the starting point (the first moment: M_1), then the current situation of separation, segregation, alienation and opposition ("*Entzweiung*") between philosophy and the natural sciences is the "negation" (the second moment: M_2): something that must be overcome, by systematically incorporating the experiences of scientific research into philosophy, while making philosophical questioning an inherent part of science. Philosophy of nature and natural science must reunite (although they will remain recognisable as *moments* within a comprehensive approach). Thus, a higher level of comprehension ("sophistication") may be reached (the third moment, the "negation the negation": M_3).

Philosophy is an active endeavour: being-at-work, a praxis of working through ("durcharbeiten"), processing and questioning the results of the natural sciences, while discerning and assessing the basic convictions (the "philosophemes") at work in them. Thus, philosophy profits from, but also critically reflects on the results of centuries of hard scientific work (p. 28). Philosophy is a dialectical endeavour, starting from abstract concepts and convictions (M_1) which are challenged and questioned by empirical findings (M_2). This dialectical process enables philosophy to understand that the real (nature) is intelligible (rational), that logos is at work in nature, so that, ultimately, genuine (comprehensive) understanding is possible (M_3).

In order to understand empirical science, philosophers should closely study it, not from a purely theoretical perspective, but as a praxis, so as to recognise how experimentation (under the sway of negativity) destroys to phenomenal object (the empirical shell, § 50, p. 132) in order to reveal the noumenal essence of nature as such. Contemplation (e.g. Eleatic thinking about being as such) gives way to experience, to active thinking (*Tätigkeit*) as a practical endeavour, exposing and assessing preliminary convictions with the help of precision instruments (thermometer, barometers, etc.), which were initially known as "philosophical instruments" (§ 7). Philosophy acknowledges and employs the validity of empirical scientific work ("*Arbeit*") and its results (§ 9, p. 52). Thinking is inherently dialectical, and this also applies to the empirical sciences (§ 11, p. 55). They offer the stimulus ("Reiz") to overcome the self-satisfying position of abstract thinking and to incorporate the conceptual results of technoscientific experience.

The term "experience" is ambiguous (§ 66). On the one hand, it refers to our experience of specific phenomena, here and now. Ultimately, however, such experiences give rise to experience in a cumulative sense (tested and validated insights). It is only because our initial a priori convictions are challenged that genuine progress can be made, while the empirical sciences are working their way towards philosophy ("entgegenarbeiten", § 12, p. 57). Indeed, philosophy owes its development to the hard work of the empirical sciences, whose results are incorporated and processed (p. 58), for logos is at work there as well. The objective of philosophy is to incorporate these partial knowledge components into a dynamically evolving encyclopaedic system, – again the result of hard work. Thus, philosophy considers the actions and products of science. While being–in–the–world (§ 19, p. 70) is a precondition for thinking, the world is affected and compromised in many ways by the activity of thinking as well, so that there is a continuous interpenetration between thinking and reality, science and environment, subjective and objective rationality, subject pole and object pole (p. 71).

In modern society, thinking itself became a real power, exercising enormous influence. So far, however, critical thinking has failed to realise its ambitions: it has been criticising, disrupting and overthrowing existing reality in many ways, but without sufficiently contributing to affirmative reconstruction and transformation. Also in the case of dialectics the emphasis has too often been on the moment of negation. Time has come to contribute more actively to the rationalisation of the real, building on and affirming its inherent rationality. Overcoming the initial position of abstract metaphysical thinking (M_1) is like a fall from grace, and intellectual labour is an "effect" of this disruption, but it is also the only way to overcome the apparent gap between the rational and the real, both in a practical sense (politics, etc.) and in an academic sense: cognitive labour as a decisive factor on the path towards reconciliation (§ 24, Z3). Technoscience can only become a vehicle for governing and transforming our world as part of a comprehensive approach.

While philosophy uses the results and experiences of science to criticise abstract metaphysics, it also assumes a critical stance towards the natural sciences themselves. Conducting empirical research means practicing metaphysics, unconsciously as it were: employing metaphysical categories, but often in a thoughtless and uncritical manner (§ 38). The empirical sciences summon us to stop roaming in empty abstraction: use your hands! (§ 38Z, p. 109), and this obviously is a valid point. Moreover, in order to acquire genuine experience, empirical science must proceed from mere observation to analysis ("Zerlegung"), must progress from object to concept. Especially in chemistry, but also in biology, analysis is vital. But analysis inevitably destroys the phenomena it studies, exerting a negative effect (§ 50, p. 132). This is most evident in research with animals and Hegel sees trials involving the decapitation of rabbits and frogs by researchers such as Treviranus, Von Haller and Legallois as "torturing" animals (§ 356Z, p. 461; cf. Rand, 2010). Negativity is a necessary evil, because the function of organs can only be studied by surgically removing them in living organisms.[7]

Technoscience is under the sway of negativity, so that a gap emerges between living phenomena on the one hand and our scientific conceptual understanding of them: a disunion ("*Entzweiung*"), which must be overcome by sublating mere observation into experience and insight. Rather than claiming that nature in itself (the thing in itself) is inaccessible to us, philosophy and technoscience (conceptual work and empirical research) join forces to disclose and come to terms with the

[7] The reverse process, organ donation, could perhaps be considered as a final anthropocentric result of destructive physiological inquiry (vivisection), and therefore as the negation of the negation.

noumenal realm, conjoining phenomenal observations with conceptual thoughts, because the noumenal real is rational. Hegel wholeheartedly rejects Kant's restriction of the scope of human knowledge to phenomena (Pippin, 2019, p. 10), positing the noumenal things-in-themselves as inaccessible. A core dialectical insight is that the noumenal realm is effectively disclosed by technoscience, via a dialectical interaction between advanced technology and advanced mathematics. Whereas premodern philosophy believed in the correspondence between thinking and things (Hegel, 1830/1986a, p. 79: M_1), modern thinking *negated* this initial position by emphasizing the gap (*Gegensatz*, *das Getrenntsein*) between human cognition and the things in themselves (M_2). Contemporary technoscience, however, has dramatically expanded not only our range of perception (via precision instruments) but also our thinking capacity (via artificial intelligence, the distributed intelligence of global research networks), giving rise to qualitative leaps in research capacity, increasingly independent of the limitations of human cognition and sensitivity, so that new research fields (e.g. quantum physics, molecular life sciences, etc.) are now able to disclose the noumenal dimension of natural objects, processes and entities (M_3). Technoscience reveals, moreover, that the noumenal entails polarity: a conjuncture of positive and negative components. On a more profound level of insight, instances of polarity prove reconcilable. Although Hegel himself, writing in the early nineteenth century, does not mention this of course, one is tempted here to think of technoscientific entities such as atoms and molecules as conjunctions of positive and negative elements (protons and electrons, matter and anti-matter, conservation and entropy, etc.), products of knowledge in which a plethora of technoscientific experiences accumulate. Although the initial results of dialectical experiments tend to be disruptive, there is an affirmative final result, as technoscientific experience is processed and sublated into genuine knowledge which, ideally, can be employed to rationalise the real, e.g. by making human practices biocompatible and less disruptive.

Dialectics and the Real

Dialectics is not a mere art or technique (§ 81), as we have seen, but the progressive self-actualisation of thinking. Abstract convictions are exposed to real-life circumstances, in order to be superseded, as we become aware of their limited validity and one-sidedness. It is by the conscious employment of dialectical principles that thinking becomes science. The basic structure of human experience is dialectical.

The same dialectic is at work in nature and reality as well however (§ 81 Z1). In nature, everything finite has the inherent tendency to move towards its opposite. Everything may be viewed as an instance of dialectics ("Alles, was uns umgibt, kann als ein Beispiel des Dialektischen betrachtet werden", § 81 Z1, p. 174).[8] Dialectics is an irresistible dynamic affecting everything. We see dialectics at work in all natural and historical phenomena, from the movement of the planets (determined by the interaction between velocity and gravity) down to complex meteorological processes (where various factors continuously interact to produce relentless change). In history, we notice how particular movements, through radicalisation (i.e. the inherent tendency of a movement to push itself towards its extreme), unwittingly strengthen or even turn over into the opposite position, so that anarchy gives rise to despotism, but this also applies to the history of science, where an overestimation of the importance of "nature" for instance, inevitably gives rise to a pendulum swing towards the opposite emphasis on "nurture" and back (Nelkin & Lindee, 1995/2004; Zwart, 2014). Rather than getting stuck in an interminable alteration of incompatible views, however, dialectics spirals towards a positive result, so that genuine progress is actually made, while that which is overcome is not completely annihilated or repressed, but rather incorporated as a constitutive moment (a guiding experience) of the subsequent position (§ 81 Z2).

Thus, the primordial Eleatic idea of being (nature, Earth) as a perfect *sphere* (M_1) was challenged by negating conceptions of infinite emptiness and erratic chance events (M_2). Eventually, however, both moments were retained in a dynamical, meteorological understanding of the earthly *atmosphere* as a relentless cyclical process of becoming and overcoming (M_3). Quality (warm versus cold, health versus disease, etc., M_1) gave way to quantity (physical measurements with the help of instruments, i.e. modern science: M_2) and, eventually, to the systemic idea of a dynamic equilibrium (M_3). The concept of the sphere is regained on a higher level of complexity, as a cyclical, meteorological process (§ 94). Likewise, the abstract concept of infinite being was negated by the recognition that all beings are finite, until both opposites were acknowledged as moments of the early modern concept of infinite space (as the negation of the negation), not as a relapse into abstract metaphysics, but as a positive result. And likewise, the combination of alkali and acid does not result in mere neutrality, but gives rise to an interactive chemical process which can be conceptually grasped, so that the conceptual (e.g. the chemical equation) is the truth of the material (e.g. of alkali and acid as material substances). Thus, mere observation evolves (via *Zerlegung*) into synthetic science and practices of recombination; so that the term "*aufheben*" means to negate and eliminate, but also to preserve ("*aufbewahren*", §96).

Another example mentioned by Hegel is the shift from Eleatic abstract being (as the first idea of Western metaphysics) to atomism (the second stage in the historical development of understanding matter). Modern scientific chemistry is only possible, however, if we realise that atoms (as material minima, as elementary particles)

---

[8] In her examination of Hegel's impact on French philosophy, Judith Butler emphasises how Alexandre Kojève rejected Hegel's "panlogistic" view of nature, seeing Hegel's doctrine of a dialectic of nature as mistaken, and subjectivity and desire as distinctive attributes of humans (Butler, 1987, p. 65). Human desire transcends biology (p. 67). Kojève's reading prefigures Sartre's view of human consciousness as that which transcends rather than unites with nature (p. 71).

should not be considered real entities, for they actually represent a metaphysical idea. Indeed, according to Hegel, atomists are metaphysicians (§98, §103).[9] What is still missing is a rational understanding of molecular entities as compositions of positive and negative components (in technoscientific terms: of protons and electrons, etc.). As Slavoj Žižek (2016/2019) convincingly argued, Hegel's criticism of Greek and modern atomism was vindicated by quantum physics, precisely because quantum physics eliminated to intuitive idea of atoms as indivisible, material particles floating in a vacuum. For quantum physics, the void is not the empty space *around* the atom (p. 39). Atoms *themselves* are weird, kenotic, empty spectres, composed of subatomic particles which result from quantum waves. Positing atoms as material particles entailed a metaphysical position. Reason commences with wholes, never with atoms, and the concept of an elementary atomic particle only works if it enables us to understand connectedness and interaction, for instance in the context of a chemical process, resulting in the synthetic construction of chemical products (as a movement from primary substance via analysis to synthesis). Hegel emphasises, moreover, that analysis and synthesis are processes which mutually refer to and depend upon one another (no synthesis without analysis; while the former is the ultimate aim of the latter).

In mathematics, we notice a similar tendency to determine a particular *quality* through *quantification* (= analysis), with the help of instruments, while both aspects are eventually incorporated in the idea of proportion ("*Maß*", §106): the unity of both (e.g. in music, architecture, chemistry, ethics, etc.). We find the same dialectics in the solar system (proportionality between velocities and orbits of planets), in the chemical composition of rocks (quantitative ratios determining qualitative characteristics) and in the shape of fossils (where we encounter similar proportional shapes both in miniature specimen and in giant ammonites). Inchoate neutrality and stability (the first moment) may temporarily give rise to disproportionality (e.g. excessive growth, the second moment) until equilibrium is restored (the third moment, §109).

An obvious example of the dialectical principle, mentioned by Hegel, is the increase or decrease of the temperature of water. Initially, such quantitative changes are captured in qualitative terms (warm, cold, lukewarm, etc.). Subsequently, these changes are quantified (with the help of a thermometer). As soon as a certain extreme is reached, however, water suddenly suffers a *qualitative* change and is converted into steam or ice (§108). A similar dialectics is at work in ethics, which is about finding the right measure (proportionality = justice; virtue = the proportionate middle between rashness and cowardice, wastefulness and thrift, etc.). Virtue is not the starting point (not a given), but a *result*. The capacity to determine the right measure is based on experience and therefore informed by instances where the limits are passed and extremities are reached. Again, the right measure is not the

[9] It is not the concept of the atom itself that Hegel considered problematic, but how it was conceived as primal and self-subsistent (Posch, 2011). Sub-atomic particles such as quarks do *not occur as self-subsistent natural unities*, but in combinations, in various modes of relatedness, as moments in nuclear processes. Therefore, while contemporary quantum physics concurs with Hegel's logic, nineteenth century "metaphysical" atomism did not.

starting-point, but a dialectical outcome (taking multiple, seemingly contradictory experiences into account). Initially, we experience matter in the primary sense, as that which is tangibly there, but in a diffuse and inchoate manner (M_1). Gradually, differences are discerned, distinctions are made and categorisations are implemented (M_2). This is basically the work of chemistry: to determine particular substances, similar to how linguistics distinguishes particular families of languages, on the basis of specific linguistic characteristics, e.g. the absence or presence of certain features (§117; §118). Eventually, this gives rise to a comprehensive, well-organised system of similarities and variations (M_3). In chemistry, the Periodic Table may count as such a result, albeit a result which, in Hegel's lifetime, was still work in progress.

Hegel also mentions the discovery of the circulation of blood, where modern anatomy initially succeeded in eliminating self-contradicting views (blood as a kind of bodily juice) by developing a purely mechanistic (machine-like) understanding, with the heart acting as a kind of pump, a view that was already questioned by Leibniz. Eventually, this mechanistic view was superseded by a more mature, organic understanding of processes occurring in living bodies (§121). The germ (in contemporary language: the genome) is the plant-in-itself ("*die Pflanze-an-sich*"), stimulated by external circumstances into a process of becoming, via interaction with exteriority and otherness: an example which already shows how mistaken the idea is that things-in-themselves are allegedly inaccessible to human cognition (§ 124Z). Likewise, we should refrain from opposing the noumenal *core* from the phenomenal *shell*, for living entities are both at the same time, Hegel argues, quoting Goethe ("*Natur ist weder Kern noch Schale/Alles ist sie mit einemmale*", §140Z, p. 275). In biological terms: living entities are both genotype and phenotype, and result from the productive tensions between the two.

All concretely existing things are a temporarily result of dialectical processes, so that chemical analysis not only means taking things apart, it also means taking a step backwards in time: from the current composite whole to the previous parts (i.e. regression), although these parts do not exist independently, but as integrated components of geologic or organic existence (§126). The limbs and organs of a body are not mere parts, because it is only in their unity that they are what they are, affected by and affecting this unity (§135n, p. 136). Limbs and organs become parts only when they fall in the hands of anatomists, who work with corpses rather than living bodies. Dissection ("*Zerlegung*") is an inevitable moment, but does not allow us to genuinely understand a living, functioning organism. Anatomical results must be incorporated in a more comprehensive, holistic view. The same applies to psychology, where specific psychic faculties should not be compartmentalised. We are what we do on the basis of our *descursus vitae*, and this notably applies to performances in art and science (§140Z, p. 277). Reality is ἐνέργεια: the realisation of an idea, which is actively at work ("*das wirkende Wirkliche*"). The abstract concept must come into existence. The ideal and the real are not in opposition to one another, they interact. The ideal has an impact on the real, while the real is not completely passive, but driven by an urge. The real is not what is empirically and accidentally given, but a process of realisation (ἐνέργεια). Technoscience uncovers the inevitable in what apparently seems contingent. The contingent will be consumed by a new reality already emerging. The immediate and accidental will be negated and consumed by self-realisation.

Hegel distinguishes three dialectical stages in modern metaphysics (§153 – §157). The first stage focussed on substance: that which necessarily exists, the given, not requiring something else, e.g. Spinoza's concept of infinite substance as God or Nature (M_1). The differentiation between cause and effect, however, gives rise to the concept of causality, as exemplified by the epistemologies of Kant and Hume, where reality is comprehended as an extended series of causal relationships between external objects, where causes give rise to effects, which become causes in their own right, giving rise to particular effects as well, and so on, ad infinitum (M_2). Eventually, however, causality gives way to the systemic idea of interaction ("*Wechselwirkung*"), where reality emerges as a process, involving multiple factors mutually affecting each other (M_3). While substance remains an abstract concept, causality is a partial process considered in isolation (in the context of a technoscientific experiment, for instance). Such artificially insulated causal relationships must become incorporated (sublated; brought to full development) in the context of a system or process: that which is real, an interactive realisation, a living substance, in which also the experimenting subjects themselves are embedded as well. Systemic interaction is the *truth* of cause and effect, which (in retrospect, from a more holistic or systemic perspective) are now mere moments.

The idea of a dialectical process also applies the "subject pole" of knowledge, to the way in which research is organised. Research requires the renunciation of our immediate (subjective, capricious) interests, biases and aims, but there is something in return, a compensation ("*Ersatz*", § 147), namely: becoming involved in a collective and evolving process of knowledge production. Thus, negative or abstract freedom gives way to concrete, positive, affirmative freedom, allowing us to endorse a collective objective, in which our talents and "energy" (in the dialectical, Aristotelian sense) can be meaningfully invested and sublated until we reach a higher plateau of understanding. Hegel emphasises the institutional embedding and embodiment of human subjectivity in general and of scientific thinking in particular (Ferrini, 2014). For Hegel, in contrast to thinkers such as Descartes, Kant, Fichte, neo-Kantians and others, the "I", the ego of science ("*Ich*", "*Ich denke*", cogito) is not a starting point, but a dialectical result of what Gaston Bachelard (1938/1970) referred to as the "formation" of the scientific spirit. A diffuse, inchoate, polymorphous individual (M_1) is exposed to the technical and practical challenges of laboratory life, is immersed in the ascetic spiritual exercises of logical and mathematical thinking, is emptied as it were (M_2), transformed into a "kenotic" subject,[10] and finally converted, reformed and edified by the logic and practice of scientific thinking, adopting the position of an accurate, self-critical and reliable producer of knowledge (M_3). Unhappy consciousness (undirected, alienated) evolves into a scientific ego,

[10] "κένωσις" refers to a process of catharsis, a cleansing of preconceptions, to become optimally receptive to the logic of science. Cf. Catharine Malabou's views on kenosis and the Pauline/Lutheran concept of "Entäußerung" (alienation; Malabou, 1996/2005, p. 82, p. 91).

as the concrete exemplification of a rational mind, for whom science is a vocation. The scientific ego is itself a concept which comes into existence via a dialectical process of self-realisation (Pippin, 1989).

From a dialectical perspective, reality is a process (ἐνέργεια), continuously in transition, an ongoing work-in-progress of becoming (§161). A plant develops out of a germ (M_1), which already contains the plant, but in an abstract manner: as a program or idea. Not in the sense that the germ is a kind of box which already contains the various components in miniature. Rather, it is a process of transition, for which the dialectical moment, the exposure to otherness (M_2) is essential. In the course of the process, the outward material form will change (in terms of quantitative expansion or metamorphosis or both), until the idea is fully and objectively realised (M_3). Whereas the germ contains the *generic* concept or idea ("das Allgemeine", A), the developmental transition takes place under *particular* circumstances and conditions ("das Besondere", B), until the plants realises and materialises itself as a concrete exemplification of the idea: as something real and *concrete* ("*Einzelheit*", E; §163). The initial idea nonetheless continues to be at work as a formative force. In other words, as soon as the germ (A, M_1) commences its process of development, a separation takes place between inside and outside, program and environment, essence and appearance (genotype and phenotype if you will): as *particular* dimensions (B, M_2). This process of differentiation continues to unfold (so that a plant will develop specific parts, e.g. roots, leaves, flowers, etc.), until the organism realises itself as a concrete mature living being, an organic whole (E, M_3). Again, the concept is not only present at the start of the process, but remains active ("*tätig*") throughout the whole trajectory of transition and realisation (§166).

The Chemical Process as a Syllogism

Rationality not only pertains to thinking, but to reality as well: rationality *realises* itself. A syllogism is not only a logical technique. For Hegel, a syllogism is something real. Dialectically speaking, everything is a syllogism. A plant, for instance, is a syllogism. Starting from a general concept (the germ), a primal process of division and differentiation is initiated, which explains why, in German, "*Urteil*" not only functions as a logical term, but also (literally) points to the process of division and differentiation ("*Teilung*") until this process is brought to its *conclusion* in the maturing plant, where the process is literally *concluded*, brought to a closure (cf. the German verb "*schließen*"). Thus, dialectically speaking, a natural process *really is* a syllogism. A similar logical structure can be discerned in inorganic chemical processes, where we start with a (neutral, general) substance (M_1), which is subsequently exposed to and brought into interaction with a *particular* environment (in the context of a chemical experiment for instance, M_2), until this process of interaction is brought to its conclusion through the formation of a stable product, as the outcome ("*Abschluss*") of the process (M_3). Allow me to zoom in on this, elucidating Hegel's understanding of the chemical process in more detail.

The chemical process is a syllogism. From source material (the general: M_1), particular substances or components are derived (via analysis, diremption or differentiation: M_2), which are then recombined, resulting in a chemical compound as product (M_3). Thus, the chemical process consists of three moments, moving from the *general* (the source material, A) which is exposed to *particular* circumstances and analysed into *particular* components (B), and finally recombined into a *concrete product*: A (M_1) → B (M_2) → E (M_3). Dialectically speaking, this is the logical structure of a chemical process. During the second moment, the components, although separated from each other, are still logically related to each other. They may even be yearning for each other: lying in wait to be reunited as it were. Even when they exist side by side, they form a whole, although this whole has to be re-established in the conclusion of the process. During the second moment of separation, they still constitute a totality (mutually referring to each other), even though they exist separately. Their one-sided existence (as opposites) is a contradiction which has to be sublated, conjoining them into the real whole (the product), thereby realising something which they, in principle, already are. This joining together (synthesis) has the structure of a syllogism, where two opposites are brought together via a third, a mediating entity: a medium, a link. As soon as this intermediary is available, the reunification may take place. The term syllogism literally (i.e. etymologically) means that two components are *thought together* (in the case of a *logical* syllogism) or, in the case of a chemical process, are *brought together* (Συλλογισμό ς = συν + λογίζεσθαι).

Etymology is an important source of insight for dialectics. From a dialectical perspective, etymology itself is a dialectical process, a syllogism, a dialectical movement of signifiers. A primal word (a *general* term, with a relatively broad range of applications) is exposed to *particular* circumstances and may respond to this exposure, for instance by evolving into a different term, by incorporating particular syllables or letters, or by combining with another term, so that a new (stable) signifier results from this, a product, whose origin or genesis may no longer be obvious. In the case of a neologism, we are faced with a conscious procedure (in chemistry, for instance, neologisms are consciously produced, in accordance with a validated method). A neologism may be regarded as a linguistic polymer, i.e. a combination of multiple units, forged together. In other words, the logic of chemistry (the chemical syllogism) has external validity and may also apply to language (to linguistic processes, so that etymology is in accordance with the logic of chemism), but also to music or to the psychology of human interaction.

The logic of chemism entails that something which is general or neutral (an earthy substance, A) is dirempted and separated into two (or more) contrasting (particular) entities (B). These substances clearly differ from one another, but their externality is not self-sufficient, so that we notice a deficit (instability), until these separate substances are conjoined together to form a concrete, stable, chemical compound (the *concrete* product, E). The components involved are not indifferent to one another. In acid-base chemistry, a base and an acid may coalesce to produce a salt (salts result from a stabilising reaction of an acid and a base). Hegel also refers to electrochemistry, notably the research conducted by Luigi Galvani concerning "animal electricity". Via metallurgy (the moment of diremption) two different metals are produced, for instance copper and zinc. As a third (intermediary) component, Galvani used a leg or a decapitated body of a frog, connecting a metal wire with the frog's spine for instance. Together, these three components (copper + zinc + decapitated body) formed a circuit, – which was demonstrated by the fact that the frog's leg or body would start to move and contract in response, indicating that, in animal bodies, electrochemistry generates contraction. When two pieces of metal are joined together (via a third, organic, intermediary component), electricity (energy) results as product.

Thus, the chemical process commences with *general* earthy substances (matter, ore). The practice of metallurgy extracts *particular* metals with the help of a furnace, resulting in, say, pieces of copper, tin or zinc, which are separated from their source materials. The Greek term μεταλλεύω means searching for or digging for metal (μεταλλεύς is a miner), so that metallurgy is a "polymer", a combination of μέταλλον and ἔργον (= work). This not only emphasises that chemistry is a hands-on practice (manual work), but also that it is inherently logical, albeit not in a bookish sense. What Hegel's logic aims to achieve is to provide a logical structure for real-life *practical* endeavours, including chemistry and metallurgy. The initial result of metallurgy is separation (diremption) of earthy matter into particular metals, which are then consciously recombined together (in the right measure and under the right circumstances) into a metal product, combining copper with zinc and tin to produce bronze for instance: a bronze spade or statue. Again, etymology (the dialectics of terms) is important here, because "metal" literally means something which is combined "with something else" (μὲτ' ἄλλο; § 332Z). The word "metallurgy" is a polymer consisting of three components (μὲτ' + ἄλλο + ἔργον), indicating how a metal worker (μεταλλουργός) *works* to combine a particular metal with *other metals*. The term "metallurgy" is itself the result of a process, forged to capture a syllogistic practice.

In the case of bronze, the result is a (relatively stable) alloy (a "concrete universal", as Hegel phrases it, representing a historical epoch, the Bronze Age). In the case of electrochemistry, the product is a set-up where the separation between the metals (say copper and zinc) is maintained, but in such a manner that the two pieces of metal nonetheless continue to interact with one another via a third component, a medium (e.g. water, or a decapitated frog, as in Galvani's trials). This set-up is a product (produced by and used by researchers-at-work). Through the subsequent work of Allesandro Volta (1745–1827), Galvani's set-up evolved into a battery, as a concrete universal, representing modern industrial society (where batteries are employed on a massive scale to create electric circuits, thereby enabling a broad spectrum of practices). This already indicates that, although Hegel did not, strictly speaking, develop a philosophy of technoscience, his logic nonetheless provides a *logical scaffold* to support technological practices, so that the elaboration of Hegel's logic into a full-fledged philosophy of technoscience is indeed an inevitable next step (Juchniewicz 2018).

It is only in laboratories that such a syllogism – from general earthy substance (A), via metallurgy (diremption, B) down to a concrete electrochemical installation (e.g. Galvani's set-up to study "animal electricity") – can be carefully studied in isolation. Real (outdoors) nature is a grandiose interplay of interlocking syllogisms ("*Wechselwirkung*"). And it is only in a living cell (as a natural laboratory) that chemical processes can be orchestrated into a self-sustaining whole. Chemically speaking, inorganic nature consists of a series of unfinished, disrupted chemical processes. As indicated, the logical structure of chemism (the chemical process as a syllogism from source material to end product) has a much broader validity and is applicable to other domains as well (Burbidge, 1996). Goethe thematised human relationships in terms of attraction, repulsion and elective affinities ("*Wahlverwandtschaften*"), whereby the latter results in a relatively stable outcome (Bates, 2014). Hegel's philosophy of chemistry is work in progress. Lavoisier's discovery of Oxygen (in 1778) heralded a scientific revolution in chemistry, turning chemistry into a rigorous science. Together with colleagues, he proceeded to publish a scientific nomenclature for chemistry, a systematic method for producing chemical neologisms and for labelling chemical compounds. This revolution generated a plethora of chemical experiments. Hegel was dissatisfied because of the conceptual (logical) deficits of this evolving research practice, this "work in progress", and his philosophy of chemistry was intended as a contribution to a more systemic and rigorous approach. Yet, his intervention remained work in progress, and a consistent chemical system was still decades away. Mendelejew introduced his periodic system in 1869. This historical process can again be framed as a syllogism in its own right. Lavoisier's initiatives represent the first moment, preparing the ground for modern chemistry by putting chemical research practices on a scientific footing, enabling a research practice resulting in baffling discoveries (Ruschig, 2001). Hegel (in his critical reflections) pointed to numerous inconsistencies and disparities between concept and reality, while at the same time aiming to contribute to the development of constructive solutions. In other words, Hegel's own work entails negativity (criticising deficits) but also points to the need for a systematic approach. Mendelejew's periodic system represents the "end" of the chemical revolution inaugurated by Lavoisier and assessed (mid-term) by Hegel. Dialectically speaking, the periodic system is the concrete realisation of the idea of nineteenth century chemistry as a systematic science.

From Syllogism to System

All natural processes are syllogisms. Chemical, biochemical or biological experiments are syllogisms studied in isolation. In a laboratory, we may study the development of a germ into a plant, exposed to a particular environment, or we may study the chemical transition of substances (exposed to a particular environment) into concrete novel compounds. Real nature is not a mere aggregate of isolated syllogisms, however, but a *cycle of syllogisms* ("*Kreislauf*", 1830/1986a, §181, p. 332), a cyclical system of interactive syllogisms. The standard format of a syllogism reflecting a natural process is: A → B → E, where a generic substance (A) realises itself into a concrete entity (E) via the exposure to particular circumstances (B). This syllogism ("*Schluss*") can be discerned in an experimental design. Other syllogisms apply as well, however, for instance when we conclude ("*schließen*") that a *concrete* cranial aquatic organism which we encounter in nature, seeing that it is lacking limbs but is equipped with *particular* organs (e.g. gills), can be considered a fish (E → B → A). In such a syllogism, a particular property (presence or absence of gills) is emphasised to subsume the living being under a general heading. It is a logical *operation* which we conduct on a daily basis, but which may also become part of a validated scientific methodology. Another example of a syllogism is: all metals (as a particular group of substances) conduct electricity; gold is a metal; ergo gold is a conductor (B → E → A). Or: Earth is a celestial body; Earth is inhabited by living organisms; ergo, other planets may be inhabited as well (the grounding hypothesis of astrobiology, the technoscience of extra-terrestrial life). Although extra-terrestrial life is a logical possibility, its realisation depends on particular circumstances (e.g. the presence of an atmosphere, of water, etc.).

A syllogism is a basic component of the logic of a discipline, but also occurs in nature. Dialectics overcomes the subject-object divide and aims to *objectify* and *realise* itself (§192). Rather than seeing nature as mere contingency, dialectics sees natural entities as the realisation of an inherent idea. Being is underway towards realisation. This is the dialectical process which evolves from general *concept* into concrete *object* (objectification): something really existing, as part of a real and interactive ambiance. An object is the transitory outcome or *product* of a dialectical process (§193). The abstract concept as such (M_1) aims to realise itself by overcoming resistance (negation, M_2), objectifying itself as something which *must* exist (M_3), albeit as something singular, and therefore transitory, bound to be consumed sooner or later. Coming into existence entails a form of indebtedness (as living beings are indebted to parents, germs, circumstances, care-givers, etc.) and they can only repay their dept by being annihilated sooner or later. The emergence of a new generation of living beings constitutes the negation of their negation.

An object is an ambiguous entity. It has independent standing, but at the same time remains dependent on its context. Moreover, an object may initially strike us as "other", but the goal of scientific research is to diminish the object's alterity by discerning the concept which reveals itself in the emerging object. The relation between subject and object, between science and reality is of a "dialectical" nature (§194 Z1, p. 351). As objectivity is a realisation of the concept, the rational is at work in the real. In other words, the object is not something inflexible, it is a *process*.

Three forms of objectivity can be distinguished (§194): a mechanism (composed of various components without any intrinsic connection); a chemical process (where components are defined by their relationships to one another) and a living being (as embodiment of an inherent telos, the realisation of an idea, in which mechanisms and chemical processes are incorporated as moments). A mechanism is an aggregate consisting of partial objects which can in principle be replaced (§195). To some extent, the body of an organism can be conceived in such terms: with limbs and organs functioning as partial objects. Yet, eventually, this conception becomes an obstacle, obstructing a more adequate understanding of living organisms. Life cannot be adequately conceived within the conceptual constraints of a mechanism (Kisner, 2008). In living entities, the mechanism is far from absent, but it is no longer the decisive principle (although it becomes more dominant in cases of disfunction). We may also notice mechanical behavioural repertoires, also in humans, e.g. in routine behaviour.

The object's objective is to strengthen its independence by affecting its environment, overcoming dependence as a contradiction. Even a stone makes the ground on which it lies more solid by its weight, so that the boulder regains its stability. We see this in the chemical process, with its tendency to move towards situations of increased stability, but also the solar system can be mentioned here as an example of an interactive process aimed at stability. Although a planet may seem a massively self-sufficiency entity (M_1), its place and position is actually determined by and dependent on gravitational relationships (M_2): a mutual struggle, resulting in systemic stability (M_3). The identity of chemical substances (M_1) is determined by their interactive differences (M_2), resulting in processes of integration (M_3). The chemical process entails a return to neutrality, but passing through turbulence and differentiation, until a more comprehensive situation of neutrality is reached: the concrete chemical product. The initial neutral substance (M_1) can be segregated into extremes (via analysis or diremption), until tension expires in regained neutrality (M_3). Thus, a chemical process consists of two steps: a diremption of what is initially indifferent ($M_1 \rightarrow M_2$) and a sublation of difference into a more integrated form of neutrality ($M_2 \rightarrow M_3$): the *product* or *conclusion* of the process.

Living beings are subjects with ends they aim to achieve. Initially, there is a negative relationship or contradiction between the objective environment as immediately given and the aims that living beings aspire to achieve. The environment is an obstacle, something to be overcome. The activities of the living being are directed towards superseding negativity and conflict, by realising a negation of the negation, which amounts to self-realisation (§204). By satisfying its needs, the living being overcomes the tension between subject and object. One-sidedness and conflict give way to embeddedness. The living organism now feels at home in its world, becomes one with its environment. The latter contains particular entities (e.g. food) which may serve as means to realise this end (§205). Accomplishing this aim is a *conclusion* in which subjectivity and objectivity, aim and object are joined together ("*zusammenschließen*"). Even survival is a syllogism. Humans are not only forced to subjugate and appropriate external objects to realise their aims, they first and foremost have to take their own body into possession, overcome its resistance, domesticate it as it were, in order to realise their (physical and spiritual) ends. Again, this self-domestication involves a transition from the body as an inchoate given (M_1) via conflict and tension (M_2) towards unification and individuation (M_3). Dialectics is not only at work at the individual level, moreover. Even if individual actors are focussed on their personal interests (opting for competition rather than for collaboration), the cunning of reason ensures that convergence prevails over disruption. Initially, for instance, the idea of a university is merely a concept (M_1), in need of students and scholars to turn it into a thriving academic community. And although tension, conflict and competition will inevitably arise (M_2), the result of the process is a concrete realisation of the idea under particular circumstances: the university as a concrete universal ("*das konkrete Allgemeine*", M_3, §210), the actualisation of the concept. A "true" university is true to its concept (§213) when instances of partiality and conflict are incorporated as inevitable moments in a process of unfolding, conjoining the ideal and the real.

Life is a concept which realises itself. In terms of contemporary science: a genome realises itself in a phenotype. The living cell is a cycle of syllogisms, of metabolic processes, such as the citric acid cycle. From the point of view of molecular biology, Hegel's conception of life as a hypercycle (a cycle of cycles) seems astonishingly adequate (Hösle, 1987, p. 314). Hegel's philosophy is *not* an a priori enterprise of pure thinking (Pippin, 2019), but an exposition of concrete scientific *experience* (§246; cf. Westphal, 2003), organising and systematising technoscientific results (Beiser, 2005, p. 108), resulting in a system, a "diamond net" of concepts, in which the formative concepts, the philosophemes at work in the natural sciences, are explicitly considered in terms of their dialectical interconnections (§246 Z, p. 20). This diamond net of concepts articulates the logos at work in technoscientific practice. Yes, all that which in nature is noisy with life, falls silent in the quietude of though (§246 Z); but this does not mean that there is a divide between a priori thinking and empirical research. Scientific experiences provide a stimulus for developing a *Logic*, while the *Logic* offers a syllogistic scaffold for natural science. In philosophy (as a rational consideration of a real process) logical thought and empirical research are brought together (Engelhardt, 1976). For Hegel, scientific experiences are realisations of a working concept. That is why chemistry and biochemistry build on triadic syllogisms and why philosophy and the natural sciences co-evolve through interaction.

Initially, the living entity (as agency) is confronted with an external reality (as otherness) which seems foreign and hostile, but eventually the living organism manages to assimilate external reality in a process of productive self-realisation. The result of living activity is not a neutral product, but individuation and self-enhancement, until, after the death of the organism, chemical processes recommence their destructive activities. In technoscientific terms: life is the relentless struggle against entropy although on the individual level, the triumph of the organic over the inorganic is a transitory situation, made perennial through reproduction. The living process is enhanced by consciousness and knowledge. And this requires an active stance (§226), as knowledge and experience result from interaction, until genuine insight is gained in a systematic fashion.

Insight requires conscious activity: analysis and diremption, reducing a concrete substance into something general (in chemistry, into elements: nitrogen, oxygen, hydrogen, etc.). This process of "*Zerlegung*" results in a contradiction, however. For instead of acquiring real knowledge about the object, the latter is actually annihilated (§227). Therefore, we need the reverse approach as well: synthesis, resulting in a concrete product. Metallurgy is the conscious recasting of basic components into something tangible and concrete (e.g. a plough, something which enhances our capacity to domesticate the environment), while plant breeding allows particular traits to become recombined, resulting in new variants as concrete agricultural products. Thus, from a dialectical perspective, scientific knowledge builds on actual human praxis and results in systematisation. The discordance between the concept and the real is overcome in the course of the process (§234), while self-contemplative thinking is the final *result* of collective processes of working-through (§236).

Extrapolations

We may further elucidate Hegel's logic with the help of some examples from contemporary technoscience. A global, transdisciplinary research area known as genomics starts from the conviction that human beings are basically determined by their genomes (their DNA), so that human beings basically *are* their genomes (a position known as genetic determinism). In a similar manner, brain researchers may claim that human beings basically *are* (determined by) their brains: the neurocentric view. Obviously, such claims are closely connected with particular technologies such as genome sequencing machines or magnetic resonance imaging (MRI) machines. Claims such as "we are our genome" or "we are our brain" articulate the metaphysical convictions materialised in such machines. On the other hand, scientists may claim (or even demonstrate in their research) that human beings are the product of their (social, cultural and physical) environments, now using different sets of tools. This collision of scientific positions (and the technologies on which they rely) results in the nature–nurture debate. Whereas life scientists or neuroscientists are more likely to opt for neuro-centrism or genetic determinism, sociologists or cultural anthropologists are more likely to adopt the "nurture"– view. We notice a pendulum swing, moreover, in the sense that during the nineteen-seventies, the nurture-paradigm was more dominant (resulting in the idea that human beings can be altered by changing their environments), while genetic determinism resurged during the nineteen-nineties, when automated genome sequencing machines were develop and the Human Genome Project was unleashed (Nelkin & Lindee, 1995/2004; Zwart, 2009, 2014).

Dialectically speaking, although genetic determinism is "negated" by research which demonstrates the importance of the environment, both research strands are logically connected. The one is the logical reverse (the "truth") of the other. They represent two stages through which our efforts to deepen human self-understanding must necessarily pass. While initially the idea that human existence is determined by our genomes seems very enlightening and productive, researchers gradually realise that this "philosopheme" is too restricted and one-sided to be convincing. A different (apparently contradictory) approach inevitably presents itself. The validity of both positions is limited, but their results allow us to understand how we may attain a more comprehensive approach in with both "moments" are acknowledged and combined as complementary views. Human existence results from the continuous interaction between both dimensions, mutually challenging each other, as interpenetrating opposites. Both moments must be recognised as partially valid. Every radical effort to understand human existence solely in terms of "nature" will strengthen the other side of the spectrum and fuel the endorsement of the contrasting view. In dialectical terms, this is known as the negation of the negation: whereas genetic determinism is *negated* by environmentalism (and vice versa), the moment of negativity and contradiction must itself be sublated (superseded, overcome), namely by developing a more comprehensive view which encompasses ("lifts up") both conflicting aspects.

Dialectics strives to capture the present in thoughts, to conceptualise the basic *truth* of a particular era, its conceptual core. The spirit (zeitgeist) of an epoch, Hegel argues, is a *general* principle which expresses itself in all *particular* domains of socio-cultural existence, including scientific research (Zwart, 2020c). Whereas the focus on nurture expressed the (more or less leftist) zeitgeist of the 1970s, the resurgence of genetic determinisms reflected the (neo-liberal) zeitgeist of the 1990s. As to our own era, globalisation could be considered our "principle": the dominant tendency towards increase of scale and planetary connectivity, but also the various forms of recoil and resistance it engenders ("fundamentalism", "populism", viral pandemics, etc.). Both contrasting tendencies are part of the same dialectical constellation, as action and reaction (Zwart, 2020a, b). Globalisation is also an important factor in contemporary technoscience, moreover, as technoscientific research is evolving into a global web of interconnected laboratories, electronic journals, research consortia and research sites. At the same time, competition between scientific superpowers (China versus the U.S., Asia versus the West, etc.) is an important trend. Dialectically speaking, this conflation of apparently contradictory tendencies (globalisation versus competition) is inevitable.

Another important principle ("philosopheme") of technoscience is the current conviction that life is becoming technologically reproducible, so that the divide between biosphere and techno-sphere, between living and non-living, natural and artificial ("synthetic"), is inevitably evaporating. This idea, that life has finally come under the sway of technoscience, is a guiding conviction for contemporary technoscientific research practices, both on the molecular micro-level (e.g. synthetic cell research) and on the meteorological macro-level (e.g. geo-engineering).

Dialectics allows us to discern the inherent logic at work in this. It entails a dynamical research program, inviting scholars to join the effort. Contrary to the position of "beautiful souls", who bemoan the current crisis while overlooking how they themselves are deeply *involved* in what they deplore (Hegel, 1807/1986; cf. Žižek, 2010, p. 399), Hegelian dialectics fosters self-reflection, making us aware of how we ourselves are always already entangled in the very processes we criticise, while also outlining emerging options to actively contribute to and become part of the imminent transition, thus pointing beyond the current crisis. Dialectics is neither a mere exegesis of oeuvres (although a careful reading of the dialectical canon is required), nor a secondary polemics. Rather, the focus is on further developing the dialectical method as a research program, emphasising its potential for addressing intellectual challenges emerging in contemporary technoscience, from synthetic biology up to climate research.

Philosophy of Nature

Hegel's *Philosophy of Nature*, the second volume of *The Encyclopaedia of the Philosophical Sciences*, is perhaps the most neglected part of his oeuvre (Engelhardt, 1976; Petry, 1987; Horstmann & Petry, 1986). Critics discarded it as insufficiently modern. Hegel seems to deny, for instance, the concept of evolution (1830/1986b, § 249), and even philosophy of nature *as such* seems to have gone out of fashion. Dieter Wandschneider (1987) already emphasised that, while in contemporary discourse epistemology and philosophy of science are flourishing, philosophy of nature is virtually non-existent. A philosophical assessment of technoscientific practice therefore requires an exercise in retrieval. Building on Aristotle, Hegel sees living beings as the realisation of the idea of life, as *logos* becoming flesh, and in the era of genomics and genetic biology, this idea seems more relevant than ever, now that this logos has assumed the concrete form of molecular letters: DNA as the program of life.

Although in the nineteenth century philosophy seemed eclipsed by remarkable breakthroughs in scientific research, Hegel argued that philosophy had a role to play precisely in such a setting (1830/1986b). There is more philosophy at work in technoscience than scientists tend to be aware of or willing to acknowledge (1830/1986b, p. 11), not only in the sense that traditional metaphysical convictions are challenged by insights produced by technoscience in a rather profound way, but also in the sense that philosophy, as the "torch-bearer" of self-consciousness (Hegel, 1818/1986, p. 402) should bring this hidden metaphysics to the fore for critical conceptual assessment. By taking up this challenge, a new dawn ("*Morgenröte*") seemed imminent for a field that had fallen silent (p. 403). The era of philosophy did not end with the rise of technoscience.

The question "What is nature?", for instance, is as daunting as it is inevitable. We may try to evade it by focussing on facts and findings of empirical research, but sooner or later the forbidding question will resurge (1830/1986b, *Einleitung*, p. 12). It is a philosophical question, but in order to address it, the natural sciences must be consulted, for it is here that the beginnings of contemporary metaphysical reflection can be discerned. There is a hidden metaphysics at work in science and the assignment of philosophy is to bring this philosophical dimension to the fore, so that we may explicitly address it (1830/1986b, § 246 Z, p. 20). To do this, we must read science from an oblique perspective, focussing on the basic, conceptual content. Thus, the sciences provide philosophy with indispensable conceptual input.

Technoscience does not approach natural entities as they immediately present themselves to us. Rather, technoscience aims to look *through* them as it were, so that questions of nature can be addressed on a noumenal level (addressing "das Innere des Innern" 1830/1986b, § 246 Z, p. 22). Rather than seeing living organisms as a unity (a Gestalt), technoscience tears its objects apart. Research entails dissection (*Zerlegung*), a destruction which reveals their inner tension (technoscience "zersplittert, zerstückelt, vereinzelt, zerreißt…" 1830/1986b, § 246 Z, p. 21). Thus, unity (oneness) gives way to polarity (twoness), although the syllogism of technoscience eventually requires a negation of the negation, i.e. a holistic turn, towards a concrete whole (e.g. the living cell), where polarity becomes complementarity and systemic interaction.

Polarity

One of the key discoveries of modern physics, according to Hegel, is the discovery of *polarity* in nature (1830/1986b, § 248, p. 30). An object (say, a piece of glass) which seems apparently neutral (M_1) may conceal an inherent tension between two opposite dimensions: positivity and negativity (M_2). This is not a purely empirical observation, but the result of active interaction with the phenomena at hand. In the case of glass, this inherent polarity can be revealed through friction, in the context of an experiment for instance. What such an experiment reveals, is polarity as an inevitable dimension of reality, as a necessary relationship between two opposites, in the sense that the positing of the one (say: positivity) inevitably entails the positing of the other (negativity), so that they together constitute unity. In other words, polarity not only involves opposition, but also the desire to overcome this opposition and to return to unity, albeit on a higher level of comprehension (M_3).

This shift from (contingent) observation to genuine understanding can also be discerned in the history of this type of research. Initially, polarity was captured in empirical (descriptive) terms, namely as "glass" ("vitreous") electricity versus "amber" ("resinous") electricity, but in the course of the eighteenth century, this distinction was reframed in more abstract symbolic terms, namely in terms of a positive (+) or negative (−) charge. This substitution of an empirical entity (glass, amber) by an abstract concept, a symbol (+ or −, positive or negative) exemplifies a shift (inevitably at work in technoscience) from the empirical (the real) to the conceptual. Technoscience basically entails a conceptualisation or symbolisation of the real (+, −), a crucial step towards genuine understanding.

Dialectically speaking, polarity (the second moment: the moment of divergence) can never be a final state, for the positive (+) necessarily refers to (or even yearns for) the negative (−). In other words, polarity strives towards its own abolishment: its sublation into regained neutrality. Thus, a third term (regained neutrality, M_3) inevitably comes into view. Polarity initially presents itself as a duality (+/−) but actually implies this third term from the very outset, so that the dual relationship is inevitably turned into a triadic one. In short: unity (M_1) gives way to duality (M_2) which in turn gives way to an abolished duality, sublated into regained neutrality (M_3).

This same dynamic can be discerned in other research areas as well. In modern chemistry, the ancient elements (earth, water, air, fire) are broken down into more elementary components: chemical elements. As Hegel explains (1830/1986b, § 328), chemistry entails analysis (*Zerlegung*) of the ancient *physical* elements (immediately visible for us, as natural phenomena) into more abstract *chemical* ones (C, O, N, H, Au, etc.). Most entities encountered in nature are mixtures or compounds, and it is only in laboratories that their purified forms can be isolated and brought to the fore: a result of negativity, dialectically speaking, because natural matter is actively taken apart (*Zerlegung*). Chemistry entails a conceptualisation of the real, systematically replacing recognisable physical elements with chemical symbols (H_2, O_2, H_2O, etc.). Water as a natural phenomenon is reduced to hydrogen and oxygen, while air is reduced to nitrogen, carbon dioxide, oxygen, etc.: the process of analysis (*Zerlegung*: $M_1 \rightarrow M_2$). Water is not only the primary substance (M_1), however, but also the product (the third term) of a chemical process ($H_2 + O_2 = 2H_2O$), the result of a synthesis ($M_2 \rightarrow M_3$). This process can be captured with the help of a dialectical formula:

M_1 (water as a physical element) → M_2 (analysis: $2H_2O \rightarrow 2H_2 + O_2$,) → M_3 (synthesis: $2H_2 + O_2 = 2H_2O$, water as a chemical compound).

In chemistry, Hegel explains, the primary substance is often referred to as the *Agent* (M_1) and the antithetical substance (drawing the Agent into a relationship of polarity or duality) as the *Other* (M_2), while the third term is the *Product* (M_3).[11] Thus, the dialectics of chemistry can be captured by the following equation:

Agent (M_1) + *Other* (M_2; revealing an antagonism: + versus –) = *Product* (M_3: the interpenetration of these two opposites, striving towards regained neutrality).

In a primal unity (M_1), an inherent contradiction is discerned (M_2), but this duality is overcome in the form of a concrete product (M_3), on a higher level of stability. In our example, the result (product) of this process is water again, but precisely *because* of this process (this experience) we now know what water (chemically speaking) *is* (on the noumenal level). From now on, we know that water is not only a physical element, but first and foremost a chemical composite.

Polarity (M_2): Agent (+) versus Other (–)
Trinity (M_3): Agent (+) + Other (–) = Product (+/–)

This same dialectical logic can be discerned in (extrapolated to) other areas of research. How to dialectically grasp, for instance, the work of Gregor Mendel? Mendel began his research with a "unity" (M_1), namely the pea plant (*pisum sativum*) as a model organism, a visible gestalt, representing life *in general* (for Mendel was not particularly interested in peas, he could have chosen a different model: he was interested in life *as such*). The sway of negativity was at work in Mendel's research practice, notwithstanding its apparent quietism. Rather than questioning nature in an aggressive manner, Mendel applied softer skills, such as painstaking brushwork. His work implied caressing rather than torturing nature, carefully moving his paintbrush among the delicate petals in order to fertilize his plants. Indeed, Mendel proved that nature reveals her secrets when she is *stroked* (Mawer, 1998, p. 61). Nonetheless, his method came down to "castrating", "de-sexing" and

[11] This syllogism from *agent* via *other* to *product* will later be taken up by Jacques Lacan, notably in his theorem of the four discourses (Chap. 4).

"emasculating" his plants. Even in Mendel's experiments there was the element of negativity or violence (Zwart, 2008, p. 204). It may require a *theory* (e.g. Hegelian dialectics) to actually *see* this (θεωρέω means "to see").[12]

In the course of his (allegedly peaceful, yet violating) pea trials, an inherent genotypic polarity was revealed (M_2), a tension between two antithetical components (the moment of *Zerlegung*, dialectically speaking), namely between *A* (the dominant factor) and *a* (the recessive factor). Mendel discovered that a recessive (hidden) element of greenness (*a*) could be present in a yellow pea plant (whose yellow alleles are dominant over the recessive green alleles). By consciously dissociating, isolating and recombining these elements or factors in various combinations, the hidden polarity was brought to the fore (M_2). This opposition (this negativity, this polarity) was sublated, however, and the antagonistic components were brought together (*aufgehoben*) into a third term: the hybrid plant (Aa) with yellow peas. This process can again be captured in the dialectical formula already employed above:

M_1 (the standard pea plant, with yellow peas) → M_2 (analysis: *A* versus *a*, dominant *yellowness* versus recessive *greenness*) → M_3 (synthesis: *Aa*, the hybrid plant form as concrete product).

A hidden duality (a *coniunctio oppositorum*) is brought to the fore, is set free, only to be abolished again by the product: the hybrid, where apparently incompatible opposites are brought together once again. In the next generation, four concrete outcomes result from this experiment (AA, Aa, aA, aa), involving pea plants whose peas can be either yellow (75%) or green (25%). In the latter case, latent otherness manifests itself. In follow-up experiments, similar polarities (Bb, Cc) were brought to the fore, so that the experiment became a full-fledged research program. Whereas yellow and green indicate phenomenal qualities (naturally visible as phenotype), Mendel's experiments revealed the noumenal "factors" at work (the genotypes), which are not immediately visible, but are represented symbolically (A, a). Therefore, the same logical structure which determines the chemical process can also be discerned in living organisms.

Agent (the unity: apparently uniform) → *Otherness* (negation, polarisation, bringing hidden otherness to the fore) → *Product* (the return to neutral unity, but on a higher level of comprehension).

Particularity (yellowness versus greenness: B) is revealed in a general, apparently homogeneous form (the initial common pea plant: A) and brought together again in the *concrete* product of hybridisation (E).

[12] A similar ambiguity can be pointed out in the case of Nobel Prize laureate and cytogenetics pioneer Barbara McClintock (1902–1992), who worked mostly with maize. Whereas Evelyn Fox Keller (1983) in her biography foregrounds the affective and sensitive aspects of McClintock's research practice, Nathaniel Comfort (2001) emphasises rationality, systematicity and the strive for control.

Domestication Domesticated

Aristotle (1980) experienced nature as φύσις, i.e.: that which emerges, comes forward on its own accord, that which has its own inherent principles of movement and change, that which is there without our doing: the first "moment" (dialectically speaking) of the human-nature relationship (M_1). Already in ancient Greece, however, this was a detached perspective: the perspective of the Master, rather than the Servant. Since the Neolithic era, the cunning of reason developed a plethora of tools and methods bent on mastering nature (Hegel, 1830/1986b, § 245), as was lucidly articulated in Sophocles' famous chorus in *Antigone* (1830/1986b, p. 13), enabling humans to use nature's particular forces *against herself*, so that technology basically represents "negativity" against nature: the second moment (M_2). Under the sway of negativity, nature became a resource for human domination and self-preservation. As natural beings, humans are exposed to instances of lack, e.g. hunger or thirst, Hegel argues: a threat to our self-preservation: a potential "negation" of ourselves by the continuous loss of energy and bio-matter (nature threatening to consume us). This negation can only be abolished by sacrificing and consuming ("negating") other natural entities, which allows us to temporarily restore our wholeness. Thus, humans as "agents" are increasingly able to effectively safeguard their own well-being, at the expense of nature as "other". Yet, as Hegel argues, this negative view entails a shallow, utilitarian understanding of our relatedness to nature, which fails to capture nature *as such*, nature on a grander scale: nature as a self-sustaining, goal-directed system or process, as something which works *through* us, and in which we remain firmly embedded. This recognition (of acting both against *and* in accordance with nature) requires a "sublation" of the (negative) utilitarian understanding into a more comprehensive view, which enables us to comprehend nature as a *process*: the self-sustaining ground and soil of our existence. Eventually, the spirit (*Geist*, i.e. the intellectual dynamical force driving human practice and human thinking) discerns and recognises itself in the dialectical dynamics at work in nature (the third moment: M_3), so that technoscience and nature can become reconciled again.

But precisely here, at this third moment, one could argue, a radical shift has taken place since Hegel developed his dialectics (Zwart, 2009). In agricultural societies, before the onset of the Anthropocene, nature and technology could perhaps still be reconciled, so that, although particular natural *entities* become damaged, disrupted and consumed by human activity, nature *as such* remains more or less intact. In the present situation, however, planetary nature *as such* (life on earth *as such*) became affected (Zwart, 2017b). Nature *as a whole* is being consumed by human consumption; nature *as such* is facing "negation" (a dynamic which eventually results in human self-negation). In other words, the third moment (M_3, the "negation of the negation") seems unattainable, as the second moment (negation: persistence in negativity) becomes rampant and runs adrift ($S_2 \rightarrow | \ S_3$). The challenge of the Anthropocene (dialectically speaking) is to once again accomplish the envisioned "negation of the negation" (M_3), but now under drastically altered conditions. Somehow, the negative sway of technoscience over nature must be "sublated", so that nature and technology can become reconciled again. This requires a critical intervention, taking us to a higher level of integration of technoscience and philosophical reflection, guiding us towards a new plateau as it were.

In other words, whereas the second moment (from the Neolithic revolution onwards) focussed on the *domestication* of nature, the anthropocenic present must domesticate technology itself, must domesticate domestication, as a particular instance of the negation of the negation. Rather than nature, technoscience itself must now somehow be "tamed", so that nature and technoscience can become "reconnected" (Blok, 2014). This will require advanced forms of practical cunning, bent on using the forces, dynamics and creativity of *technoscience itself* in order to effectively *subdue* its negativity: the basic ambition of a particular strand of technoscientific research known as biomimicry (Benyus, 1997; Plumwood, 1993; Van Hout, 2014; Blok & Gremmen, 2016; Zwart et al., 2015; Zwart, 2019b). In a similar vein, Yuk Hui (2016, 2019) refers to the unification of nature and technology, cosmos and culture through technical activities as "cosmotechnics". Dialectics allows us to envision both technoscience and nature as interactive, dynamical systems.

Nature is no longer invulnerable (beyond our grasp). Nature and technoscience are currently seen as being in contradiction with one another, and this is not only a logical, but also a practical contradiction, so that technoscience becomes a *disruptive* factor. The negation of the negation requires as *sublation* of technoscience into a bio-compatible (sustainable) endeavour. As Hegel himself was not yet an Anthropocenic thinker, his diagnostics of the present must be updated (on the basis of his dialectical method). Two key insights seem highly relevant in this respect: Hegel's view of planet Earth as a systemic whole and Hegel's views concerning the "end" of natural evolution.

Planet Earth as a Terrestrial Organism

According to Hegel, our planetary environment constitutes an "elementary, meteorological process" (1830/1986b, § 286). Whereas planet Earth once began as a geosphere (a terrestrial system, an interactive accumulation of inorganic chemical processes), life emerged, eventually giving rise to a global meteorological process (a global ecosystem, in contemporary terms). This view resulted from Hegel's critical assessment of the discrepancies between the insights produced by laboratory research and the real, meteorological processes in outdoors nature, which seemed too complex to be comprehended in laboratory terms (Zwart, 2017b). Initially, modern technoscience studies causal relationships in isolation, probing the pressure, temperature or composition of air and water with the help of laboratory devices (barometers, hygrometers, etc.) to establish causal relationships. Yet, in the real atmosphere, such laboratory equipment is absent, Hegel argues, and laboratory knowledge cannot be meaningfully extrapolated into nature as a whole. It is the conviction of modern experimental science that what happens outdoors (in the open) should concur with processes that are studied under controlled laboratory circumstances, but that is a mistake, as laboratory work consistently fails to replicate meteorological processes. According to Hegel, this is due to the fact that these research practices do not really regard atmospheric phenomena as moments *of a whole*, as aspects of a comprehensive planetary process, in which planet Earth as such is involved as the "universal individual" (*das allgemeine Individuum*, 1830/1986b, p. 155), with a metabolism of its own. Science aims to differentiate this whole into a limited set of particular causal relationships, but by so doing it proves unable to realise its goal. The reductionist obsession is nonetheless important because all these (finite, particular) experiments eventually culminate in one crucial *experience* (which is the ultimate *truth* of laboratory science), namely that planet Earth must be regarded as a complex, infinite *process*, a terrestrial *whole*, – an insight which reveals the one-sidedness of the reductionist premises on which laboratory research builds. In order to really *understand* nature, science must develop a much more holistic meteorological approach. In schema:

Nature in general as φύσις (M_1) → Nature as a set of causal relationships (technoscientific reductionism as the negation of the primordial whole: M_2) → the awareness that nature constitutes an atmosphere, a meteorological process (the terrestrial system as the ultimate *truth* of technoscientific reductionism: M_3).

Present-day meteorology and climate research, relying on big data and systemic modelling, may actually embody this "holistic turn" (M_3) promoted by Hegel (Zwart, 2017b). Technoscience is studying the metabolism of Earth as such. With the help of *in silico* programs, the complex dynamics of weather and climate are monitored. Precisely at this point, however, something has dramatically changed. Precisely in the context of these powerful research practices, a disconcerting truth is revealed, namely that we are no longer facing an "elementary" process. Geochemistry is irrevocably tainted by human influence, so that human activity *itself* became a decisive, "elementary" factor. In contemporary climate research, technoscience monitors its own disruptive global impact.

Although Hegel urges us to see the planet as an individual whole, he essentially sees Earth as a petrified being, a gigantic, spheroid amalgam of crystals and brittle, not *really* a living organism. As he phrases it, planet Earth is *implicitly* alive: the ground and soil of life as such. On the planetary level, the general terrestrial process remains a meteorological process (1830/1986b, p. 289), the comprehensive result of a plethora of finite, physical and chemical processes. Whereas other substances are dissolved, Earth as such cannot be consumed, but continuous to persist. Therefore, the chemistry of planet Earth (terrestrial nature) is "meteorology" (p. 291), the inorganic geochemistry of nature as a whole. Hegel sees Earth as a frame of life, even as an "individual", but the earthly super-individual lacks self-awareness. It is a paralysed, frozen, petrified form of life (§ 337). Still, Earth must be conceived as a totality. Its global process is perennial.

In the chemical processes actually taking place on this planet, Hegel discerns a "semblance" of life (§ 335). Life is the "truth" of the chemical process (Hösle, 1987). An *implicit* vivacity is at work in planetary existence, but it realises itself in something else, namely in the living organisms which are sustained by the earthly system. In contrast to a (finite, inorganic) chemical process, organisms are described by Hegel as self-sustaining processes (§ 336). Whereas inorganic substances are continuously exposed to transformative pressures, living beings (exposed to similar external dangers, to "negating otherness") prove able to endure the tension, so that they persevere, and even reproduce themselves. Hegel conceives the transition from inorganic to organic nature as one from prose to poetry (§ 336Z), for while chemical processes take place continuously in multiple directions, life is self-contained. Planet Earth on the other hand is not an organism, and does not reproduce itself, but nonetheless sustains herself (§ 339).

Hegel sees excrements and waste products of living beings as symptoms of error (§ 365; Kingston, 2013), indicating a lack of adjustment between self and other, organism and environment, as food is only partly digestible. In excrements, the metabolism of life becomes chemistry again, as organic by-products, bound to decay. Although Hegel was unaware of course of current insights concerning the active role of the microbiome as our extimate organ, Hegel emphasises that excrements are a *product*: they are not mere negativity, mere waste (i.e. useless indigestible material) because, in the course of the process of digestion, the organism adds to it and actively expels it. Everything is a syllogism, and this also applies to digestion and defecation: food (M_1) is digested (M_2), a process of biochemical diremption, where bodily fluids trigger nutrition to decompose, so that food is negated and annihilated, but the end result (faeces) is a product as well, a combination of remnants and additives (M_3). On the collective level, excrements are part of the metabolism between human culture and the global environment. Seen from this perspective, global disruptive pollution is a symptom of systemic error, signalling the non-sustainability of the current global economy.

Again, although Hegel himself was not yet a thinker of the Anthropocene, his dialectics helps us to articulate what is currently at stake. Under anthropocenic conditions, the earthly process *as such* can no longer be regarded as infinite or self-contained. The ground and soil of life can no longer be taken for granted and may even be made uninhabitable. This awareness entails a planetary form of self-awareness, in the form of the global Anthropocene-debate. As if, in the face of the possibility of annihilation, Earth finally becomes a planetary "subject" (albeit as yet incapable of concerted action). And precisely at this moment, the option of planetary self-reproduction emerges, namely the idea of transplanting terrestrial life to other planets, whose surfaces and atmospheres may now become infected with life (once Earth has been exhausted and "consumed"); for instance, by *terraforming Mars*.[13]

[13] This line of thinking will be taken up in Chap. 7, devoted to the dialectic phenomenology of Teilhard de Chardin.

Hegel and the End of Evolution

Although natural evolution continues to evolve, at its own (imperceptibly slow) pace, the history of life as we know it has reached its completion in the sense that, from now on, Darwinian evolution will be eclipsed by the imminent Cambrian explosion of neo-life forms: the assembly-line production of new, human-made organisms, at an astonishingly high speed, reflecting the era of the technical reproducibility of life: a "negation" of natural evolution, a reassembly of life forms at a higher level of aggregation. Viruses are the exception, evolving continuously and at a high pace, but the current discussion whether the COVID-19 virus spread via a "wet" animal market or leaked from a laboratory, is nonetheless symptomatic of this trend (Andersen et al., 2020; Zwart, 2020a).

This may shed a fresh light on Hegel's highly controversial (Wandschneider, 2002; Houlgate, 2005) views on evolution. Hegel sees the successive geological formations disclosed by modern research as evidence of the "massive changes" and "tremendous revolutions" that must have occurred in a distant geological past (1830/1986b, § 339). Yet, for Hegel, these processes have now come to a stand-still more or less, and he explicitly rejects the idea of an on-going evolution of species. He even regards fossils (notably shells discovered in older geological stratums) as petrified remnants of faltered natural experiments: the debris of previous efforts of nature to forge organic forms (p. 359). Elsewhere (§ 367), however, Hegel explicitly acknowledges that organisms (both as individuals and as species) adapt themselves to external environmental circumstances (both biotic and abiotic), so that the original type may be modified in various directions. In other words, he acknowledges the plasticity of life (Malabou, 1996/2005) in response to environmental pressures.

Hegel's views on evolution are both remarkable and self-contradictory. Remarkable because nothing in his philosophy seems to justify an outright *rejection* of the idea of the evolution of species (Houlgate, 2005). Rather, evolutionary thinking seems quite compatible with his idea of life (Hösle, 1987). It is also self-contradictory, for why should Hegel endorse dramatic geological "revolutions" while explicitly discarding evolution in the realm of living beings? The idea of evolution also concurs with Hegel's views on the origin of life. For Hegel, there is already a glimpse of vitality in chemical processes (Hegel, 1830/1986b, § 335 Z; Ferrini, 2011, p. 208) and the move from chemistry to biochemistry (to the metabolism of life, as self-sustaining biochemical hypercycles) is already implicitly present in prebiotic chemistry. Life, according to Hegel, is a self-renewing chemical process made perennial (Zwart, 2020a, p. 372). Once, according to Hegel, the Earth was in a state where no living things but only chemical processes existed (Hegel, 1830/1986b, § 339 Z, p. 349). Here, life suddenly emerged, as if the whole planet became fertilised with life, and micro-organisms, infusoria ("Infusionstierchen", p. 363), as punctiform maritime vitality arose, through *generatio aequivoca* (§ 341).

Hegel's arguments gain an unexpected coherence, however, when reconsidered from an anthropocenic perspective. Whereas (slow) geological (abiotic) change and Darwinian (biotic) evolution has taken place in the past, in the present situation these processes are eclipsed and overtaken by the global impact of technoscience. Darwinian evolution may continue, in its own super-indolent pace, but will increasingly be overshadowed by the rapid and dramatic transformations unleashed (directly and indirectly) by modern technoscience, so that Darwinian evolution *de facto* becomes increasingly irrelevant. Compared to the extremely high pace of self-directed, technology-driven processes of selection, extinction, migration, adaptation and even creation (the production of neo-life by synthetic biology, fuelled by the anthropocenic transition), natural random evolution becomes something marginal (with the exception of viral evolution perhaps). In other words, the anthropocenic present basically represents the "end" of (Darwinian) evolution: the end of *natural* history, not in the sense that this type of change no longer happens at all, but in the sense that its impact is dwarfed by the much more immediate and dramatic impact of anthropocenic processes unleashed by technoscience, – ranging from pollution, climate change and ecological disruption up to synthetic biology, biological enhancement and the production of neo-life –, which irrevocably affect the present conditions and future prospects of life on Earth.

This also concurs with the finale of Hegel's philosophy of nature, where he states that the spirit increasingly recognises itself in nature (1830/1986b, § 376). Via technoscience the spirit incessantly absorbs the processes of nature it uncovers, sublating them into something which is rational, technological and artificial (denaturalising the technologies and processes of nature, resulting in bio-technical and techno-natural hybridisation). Moreover, while there is recalcitrance at work in nature when it comes to realising its own possibilities and concepts, the spirit (in the form of technoscience) may now attempt to break this cycle of natural "inadequacies" (the violence, suffering, waste, etc. entailed in natural existence) by self-consciously bringing forth what is implicitly inherent, but not actually realised by nature: a drastic enhancement ("sublation") of nature. As indicated, this line of thinking will be taken up in Chap. 7, where we discuss the dialectic phenomenology of Teilhard de Chardin.

Dialectics of Technoscience

Hegel's logic also applies to the practice of studying Hegel. Hegel's oeuvre represents the point of departure, the groundwork (the first moment), but it is not a *creatio ex nihilo*, of course. Rather, it is a product (the outcome of a syllogism) in its own right. For Hegel himself, Aristotle constituted the groundwork, with the scientific revolution as the anti-Aristotelian "negation", triggering a response (inciting a negation of the negation). What Hegel, as a modern Aristotle, aimed to achieve, was to supersede the contradiction by fleshing out that Aristotelian dialectics actually concurs with modern science: that both moments are direly in need of (and will significantly benefit from) this mutual exposure. This, one could argue, is the basic objective of Hegel's oeuvre. It is not an effort to overcome or complete the work of Kant (Pippin, 1989, 2019) or Fichte (Beiser, 2005), but rather to achieve what

Aristotle had done for ancient thinking: coming to terms with modern history, politics, technoscience and art in a profoundly philosophical manner.

If we take Hegel as commencement, as source material (first moment), the second moment is represented by Hegel studies. Hegel scholars (epigones) and Hegel critics produced and continue to produce an immense discourse which inevitably diffracts into particular schools and fashions (the moment of diremption). We notice a basic contradiction here, however. Hegel himself was not a Hegel scholar at all (nor a Kant or Fichte scholar, as for him, author studies constituted a "moment" within a more ambitious program). In sharp contrast to Hegel studies scholarship, Hegel's own work was not exegetic at all. Rather, what he aimed to achieve was: developing a logical system to address the political, technoscientific and spiritual challenges of the modern epoch. Although this involved a careful reading of previous philosophical oeuvres, this was not an end in itself. Rather, the aim was to extract conceptual building blocks from previous efforts, highlighting their inconsistencies, in order to produce a consistent philosophical system (a diamond net) which allows us to put philosophy on a scientific footing (like Lavoisier had done for chemistry), through the development of a dialectical methodology and nomenclature.

In other words, although Hegel scholarship is important in its own right, it yearns for and prepares the ground for something else, namely a philosophical practice more in line with Hegel's own ambition: seeing dialectics as a philosophical assessment of the present, a dialectics of techno-politics and technoscience. Whereas Hegel studies meticulously compare Hegel's work with previous oeuvres (Schelling, Fichte, Kant, Spinoza, etc.), a dialectics of technoscience aims to live up to Hegel's own understanding of what philosophy is and should be, a critical confrontation with the contemporary world of techno-politics and technoscience. From a Hegelian perspective, dialectics of technoscience is not "applied" philosophy, it is *philosophy*, in the genuine sense of the term.

Although Hegel is not generally considered a philosopher of technology (Hubig, 2000), if we follow the inherent logic of his thinking, a dialectics of technology or technoscience is the inevitable next step, as Natalia Juchniewicz (2014, 2018) convincingly argued. The first Hegelian to develop a philosophy of technology was Ernst Kapp (1877/2015), a German émigré who took Hegel's *Werke* with him to the Texan plains. His *Grundlinien einer Philosophie der Technik* ("Elements of a Philosophy of Technology") elaborate Hegel's outlines and constitute a synthesis, so that Hegel's grounding work (M_1), via the exposure to the experience of emigration to the New World (M_2), resulted in one of the first modern treatises on the philosophy of technology: Kapp's monograph as concrete product (M_3) and as a synthesis of the author's exposure to Hegel (as a German gymnasium professor) and his subsequent exposure to hands-on rural labour in Texas (Maye & Scholz, 2015, p. 8).

For Kapp, technology is the self-externalisation of the spirit. The starting point of his philosophy of technology is indeed remarkably similar to Hegel's philosophy of spirit (the third part of the Encyclopaedia: Hegel, 1830/1986c). According to Kapp, implicitly citing Hegel, the basic objective of a history of technology is *self-knowledge* (Kapp, p. 17; cf. Hegel § 377). We study technology to know ourselves, and to understand history as the self-realisation of human culture. The spirit is not something merely spiritual (cf. Hegel: "kein Seelending"), but *activity*, and intimately connected with the body and the material world (Hegel, 1830/1986c, § 378 Z, p. 12). Tools are externalisation of the spirit, projections of organs into the outside world, transforming matter into extended organs, allowing us to interact with and grasp the natural world with more strength, dexterity and precision. The human hand plays a threefold role, Kapp argues (p. 51): it is an instrument as such, but it also provides a model for other tools and artefacts (a hammer resembles a fist, etc.). Finally, it is the tool or instrument which allows us to produce these other tools and instruments. It is by transforming the world that we become ourselves, that we realise our concept. We humans are self-made, and the history of technology is the realisation of self-consciousness.

According to Hegel, technology co-evolved with human labour and the first mode of labour was compulsory work, choosing life over the risk of death, the obligation to work for the Lord or Master in the context of an agricultural ambiance (Hegel, 1807/1986; Juchniewicz, 2014). The ground for these ideas, elaborated in *Phenomenology of the Spirit*, notably the dialectic of Master and Servant, was prepared in unpublished fragments, written during Hegel's Jena years. Agricultural and horticultural labour are *mechanical*, Hegel argues, in a fragment written in Jena in 1802/1803 and known as *System der Sittlichkeit*, compelling plants to produce biomaterials, while the taming of animals entailed a combination of compulsion and trust. The next stage is *chemical* labour (metallurgy, ceramics, etc.). The middle term (the mediation) between subject and object is the tool (the hammer, the furnace, etc.): itself a product (the materialisation of a concept: consciousness transformed into a thing), but also, as Hegel phrases it, the persistent "norm" of labour, because the handling of such tools requires significant skill. Thus, we may distinguish mechanical, chemical and biological tools (e.g. ploughs, fertilisers and yeast respectively). The attitude of artisans towards their tools is one of veneration, Hegel notices, while the workers' attitude towards their products is desire held in check. The most important product of technology, however, is a new mode of human existence, as the Servant becomes a highly skilled artisan, while labour becomes a social activity (craftmanship). Subsequently, labour is replaced by, or outsourced to, machines.

We notice this same dialectic in technoscientific labour (i.e. knowledge production). The initial researcher is a Servant, for instance a scribe, labouring for a lord or master (as a palace scribe, a monk, etc.). In the course of history, however, knowledge workers produce sophisticated contrivances (which not only serve as intermediaries between subject and object, but also set *norms* in terms of precision, accuracy and craftmanship for the research practice involved), while these individuals transform themselves into skilled artisans of knowledge. The menial aspects of research tend to be out-sourced to machines (alienation), although one could argue that in the era of technoscience, this not only applies to the monotonous handiwork of science, but to brain work as well: to thinking as such (Habermas, 1968/1973), so that humans eventually become mere operators, highly dependent on their equipment.

They themselves increasingly become components within complicated networks of machines: "living accessories" in a machine park.

In line with Hegel's logic, three modes of machines emerge in the course of the history of knowledge. First of all, mechanical machines (clockworks, weighing scales, etc.) which function in a quantitative manner (dissecting the world, parcelling out quantities). The next step is the chemical machine (electrolysis machinery, for instance), where quality and proportion become increasingly important. And the third step is a biological machine (e.g. *Caenorhabditis elegans* or nude mice as animal models) where the organism's inherent goal-oriented (teleological) behaviour is exploited for research. The final step are the intelligent machines currently emerging, from advanced computers up to synthetic cells, especially developed for research. In other words, we notice a gradual displacement from labouring bodies via mechanical machines to sophisticated technoscientific hybrids. In technoscientific research we see the *Geist* at work, sublating the subject-object divide (posited by Descartes, Kant, Mach and many others) through practical and intellectual activities (Juchniewicz, 2018) in the context of an institutionalised practice, while planet Earth (a geosphere which at a certain point gave rise to a biosphere) currently develops into a noosphere (a technoscientific global web; cf. Chap. 7).

References

Andersen, K., Rambaut, A., Lipkin, W. I., Holmes, E., & Garry, R. (2020). The proximal origin of SARS-CoV-2. *Nature Medicine, 26*, 450–455.

Aquinas, T. (1922). *Summa Theologica*. Marietti.

Aristophanes. (1962). Clouds. In *The complete plays of Aristophanes*. Bantam Books.

Aristotle. (1993). *Metaphysics* (Loeb ed.). Harvard University Press/Heinemann.

Aristotle. (1980). *Physics* (Loeb ed.). Harvard University Press/Heinemann.

Aristotle. (1986). *De Anima/On the Soul* (Loeb ed.). Harvard University Press/Heinemann.

Bachelard, G. (1938/1970). *La formation de l'esprit scientifique: Contribution à une psychanalyse de la connaissance objective*. Vrin.

Bates, J. A. (2014). Confusing matters: *Romeo and Juliet* and Hegel's *philosophy of nature. Memoria di Shakespeare. A Journal of Shakespearean Studies, 1*, 173–201. https://doi.org/10.13133/2283-8759

Beiser, F. (2005). *Hegel*. Routledge.

Benyus, J. (1997). *Biomimicry: Innovation inspired by nature* (p. 1997). HarperCollins.

Blok, V. (2014). Reconnecting with nature in the age of technology: The Heidegger and radical environmentalism debate revisited. *Environmental Philosophy, 11*(2), 307–332. https://doi.org/10.5840/envirophil20149913

Blok, V., & Gremmen, B. (2016). Ecological innovation: Biomimicry as a new way of thinking and acting ecologically. *Journal of Agricultural and Environmental Ethics, 29*, 203–217. https://doi.org/10.1007/s10806-015-9596-1

Browning, G. K. (2000). Marx's doctoral dissertation: The development of a Hegelian thesis. In T. Burns & I. Fraser (Eds.), *The Hegel-Marx connection*. Palgrave Macmillan. https://doi.org/10.1057/9780230595934_6

Burbidge, J. W. (1996). *Real process: How logic and chemistry combine in Hegel's philosophy of nature*. University of Toronto Press.

Butler, J. (1987). *Subjects of desire. Hegelian reflection in twentieth-century France*. Columbia University Press.

Comfort, N. (2001). *The tangled field: Barbara McClintock's search for the patterns of genetic control*. Harvard University.

De Boer, K. (2010). *On Hegel: The sway of the negative*. Palgrave Macmillan.

Delbrück, M. (1971). Aristotle-totle-totle. In J. Monod & E. Borek (Eds.), *Of microbes and life* (pp. 50–55). Columbia University Press.

Diogenes Laertius. (1925/1972). *Lives of eminent philosophers* (Loeb Classical Library). Harvard University Press/Heinemann.

von Engelhardt, D. (1976). *Hegel und die Chemie Studie zur Philosophie und Wissenschaft der Natur um 1800*. Guido Pressler Verlag.

Ferrini, C. (2011). The transition to organics: Hegel's idea of life. In S. Houlgate & M. Bauer (Eds.), *A companion to Hegel* (pp. 203–224). Blackwell.

Ferrini, C. (2014). From disparagement to appreciation: Shifting paradigms and interdisciplinary openings in interpreting Hegel's philosophy of nature. *Esercizi Filosofici, 9*(1), 1–13.

Habermas, J. (1968/1973). *Erkenntnis und Interesse*. Suhrkamp.

Hegel, G. W. F. (1807/1986). Phänomenologie des Geistes. In *Werke 3*. Suhrkamp.

Hegel, G. W. F. (1818/1986). *Rede beim Antritt des philosophischen Lehramtes an der Universität Berlin* (Werke 9) (pp. 399–420). Suhrkamp.

Hegel, G. W. F. (1830/1986a). *Enzyklopädie der philosophischen Wissenschaften I: Die Wissenschaft der Logik* (Werke 8). : Suhrkamp.

Hegel, G. W. F. (1830/1986b). *Enzyklopädie der philosophischen Wissenschaften II: Die Naturphilosophie* (Werke 9). : Suhrkamp.

Hegel, G. W. F. (1830/1986c). Enzyklopädie der philosophischen Wissenschaften III: Die Philosophie des Geistes. Werke 10. Suhrkamp.

Hegel, G. W. F. (1831/1986). *Wissenschaft der Logik II* (Werke 6). Suhrkamp.

Hegel, G. W. F. (1971). *Vorlesungen über die Geschichte der Philosophie I* (Werke 18). Suhrkamp.

Horstmann, R.-P., & Petry, M. J. (1986). *Hegels Philosophie der Natur: Beziehungen zwischen empirischer und spekulativer Naturerkenntnis*. Hegel-Vereinigung/Klett-Cotta.

Hösle, V. (1987). *Hegels System: der Idealismus der Subjektivität und das Problem der Intersubjektivität. Band 2: Philosophie der Natur und des Geistes*. Hamburg.

Hottois, G. (1979). *L'inflation du langage dans la philosophie contemporaine*. Éditions de l'Université de Bruxelles.

Houlgate, S. (2005). *An introduction to Hegel: Freedom, truth and history*. Blackwell.

Hubig, C. (2000). Macht und Dynamik der Technik – Hegels verborgene Technikphilosophie. In R. Bubner (Hg.), *Die Weltgeschichte – Das Weltgericht?* (S. 335–343).

Hui, Y. (2016). *The question concerning technology in China: and essay in cosmotechnics*. Falmouth: Urbanomic Media.

Hui, Y. (2019). *Recursivity and contingency*. London / New York: Rowman & Littlefield.

Juchniewicz, N. (2014). The possibility of technology in the philosophy of Hegel. *Hegel-Jahrbuch, 2014*(1), 242–247. https://doi.org/10.1515/hgjb-2014-0140

Juchniewicz, N. (2018). Dialectical technology. Hegel on means, tools and the machine. *Filozofia, 73*(10), 818–830.

Kapp, E. (1877/2015). *Grundlinien einer Philosophie der Technik*. Hamburg: Felix Meiner.

Kingston, A. (2013). *Hegel's unconscious: Analysing matter in the philosophy of nature*. Electronic Thesis and Dissertation Repository. https://ir.lib.uwo.ca/etd/1478

Keller, E. F. (1983). *A feeling for the organism: The life and work of Barbara McClintock*. W.H. Freeman and Company.

Kisner, W. (2008). The category of life, mechanistic reduction, and the uniqueness of biology. *Cosmos and History: The Journal of Natural and Social Philosophy, 4*(1-2), 113–153.

Lemmens, P., & Hui, Y. (2017). Reframing the Technosphere: Peter Sloterdijk and Bernard Stiegler's anthropotechnological diagnosis of the Anthropocene. *Krisis: Journal of Contemporary Philosophy, 2*, 26–41.

Levins, R., & Lewontin, R. (1985). *The dialectical biologist*. Harvard University Press.
Malabou, C. (1996/2005). *The future of Hegel: Plasticity, temporality and dialectic*. Routledge.
Mawer, S. (1998). *Mendel's dwarf*. Penguin Books.
Maye, H., & Scholz, L. (2015). Einleitung. In E. Kapp (Ed.), *Grundlinien einer Philosophie der Technik*. Felix Meiner.
Nelkin, D., & Lindee, S. (1995/2004). *The DNA mystique: The gene as a cultural icon*. University of Michigan Press.
Petry, M. J. (Ed.). (1987). *Hegel und die Naturwissenschaften*. Frommann-Holzboog.
Pippin, R. (1989). *Hegel's idealism: The satisfactions of self-consciousness*. Cambridge University Press.
Pippin, R. (2019). *Hegel's realm of shadows*. University of Chicago Press.
Plumwood, V. (1993) Feminism and the mastery of nature. London: Routledge.
Posch, T. (2011). Hegel and the sciences. In S. Houlgate & M. Baur (Eds.), *A companion to Hegel* (pp. 177–202). Blackwell.
Rand, S. (2010). Animal subjectivity and the nervous system in Hegel's philosophy of nature. *Revista Eletrônica Estudos Hegelianos, 7*(12), 1–16.
Ruschig, U. (2001). Logic and chemistry in Hegel's philosophy. *HYLE – International Journal for Philosophy of Chemistry, 7*(1), 5–22.
Schrödinger, E. (1944/1967). *What is life? The physical aspect of the living cell*. Cambridge University Press.
Van Hout, S. (2014). *'It's alive! Ecological genomics and the promise of a new relationship with nature'*, PhD thesis. Nijmegen: Radboud University.
Wandschneider, D. (1987). Die Stellung der Natur im Gesamtentwurf der hegelschen Philosophie. In M. Petry (Ed.), *Hegel und die Naturwissenschaften* (pp. 33–64). Frommann-Holzboog.
Wandschneider, D. (2002). Hegel und die Evolution. In O. Breidbach & D. von Engelhardt (Eds.), *Hegel und die Lebenswissenschaften* (pp. 225–240). VWB.
Westphal, K. (2003). *Hegel's epistemology: A philosophical introduction to the phenomenology of the spirit*. Hackett.
Žižek, S. (2010). *Living in the end times*. Verso.
Žižek, S. (2012/2013). *Less than nothing: Hegel and the shadow of dialectical materialism*. Verso.
Žižek, S. (2016/2019). *Disparities*. Bloomsbury.
Zwart, H. (2008). *Understanding nature. Case studies in comparative epistemology*. Springer.
Zwart, H. (2009). Biotechnology and naturalness in the genomics era: Plotting a timetable for the biotechnology debate. *Journal of Agricultural and Environmental Ethics, 22*, 505–529.
Zwart, H. (2014). Book review. Dorothy Nelkin and M. Susan Lindee, The DNA mystique: The gene as a cultural icon. *Sociology, 47*(5), 1030–1032.
Zwart, H. (2017a). The oblique perspective: Philosophical diagnostics of contemporary life sciences research. *Life Sciences, Society & Policy, 13*, 4. https://doi.org/10.1186/s40504-017-0047-9
Zwart, H. (2017b). From the nadir of negativity towards the cusp of reconciliation: A dialectical (Hegelian-Teilhardian) assessment of the anthropocenic challenge. *Techné: Research in Philosophy and Technology, 21*(2–3), 1–24. https://doi.org/10.5840/techne20176565
Zwart, H. (2018). *In the beginning was the genome: Genomics and the bi-textuality of human existence*. The New Bioethics: A Multidisciplinary Journal of Biotechnology and the Body. https://doi.org/10.1080/20502877.2018.1438776.
Zwart, H. (2019a). *Psychoanalysis of technoscience: Symbolisation and imagination* (Series: Philosophy and Psychology in Dialogue). LIT Verlag. ISBN:978-3-643-91050-9.
Zwart, H. (2019b). What is mimicked by biomimicry? Synthetic cells as exemplifications of the three-fold biomimicry paradox. *Environmental Values, 28*(5), 527–550. https://doi.org/10.3197/096327119X15579936382356
Zwart, H. (2020a). Emerging viral threats and the simultaneity of the non-simultaneous: Zooming out in times of Corona. *Medicine, Health Care & Philosophy: A European Journal.* https://doi.org/10.1007/s11019-020-09970-3

Zwart, H. (2020b). Science and suspicion. Maxim Gorky's *Children of the Sun* as a critical mirror in times of COVID-19. *Law, Culture and the Humanities*. https://doi.org/10.1177/1743872120968053

Zwart, H. (2020c). *Styles of thinking* (Series: Philosophy and Psychology in Dialogue 2). LIT Verlag. ISBN:978-3-643-96300-0.

Zwart, H., Krabbenborg, L., & Zwier, J. (2015). Is dandelion rubber more natural? Naturalness, biotechnology and the transition towards a bio-based society. *Journal of Environmental and Agricultural Ethics, 28*, 313–334. https://doi.org/10.1007/s10806-015-9536-0

Chapter 3
Dialectical Materialism

Introduction

Although Karl Marx and Friedrich Engels strictly speaking never used the term, "dialectical materialism" refers to the philosophy of science and nature developed in (and on the basis of) their writings, emphasising the pivotal role of real-world socio-economic conditions (e.g. labour, class struggle, technological developments).[1] As indicated by their correspondence (Marx & Engels, 1983), their collaboration represented a unique intellectual partnership which began in Paris in 1844 and continued after Marx's death, when Engels took care of Marx's legacy, notably the sprawling mass of manuscripts which he managed to transform into Volume II and III of *Capital*. While their joint effort (resulting in no less than 44 volumes of collected writings known as the *Marx Engels Werke*, published by Dietz Verlag Berlin) began as co-authorship, they eventually decided on a division of labour (with Marx focussing on *Capital*), although reading, reviewing, commenting on and contributing to each other's writings remained an important part of their research practice. As a result of this division of labour, while Marx focussed on political economy, Engels dedicated himself to elaborating a dialectical materialist philosophy of nature and the natural sciences, resulting in works such as the *Anti-Dühring* and his unfinished *Dialectics of Nature* (published posthumously), although Engels (a voracious intellectual) wrote and published on may other topics as well, so that his output can be regarded as a dialectical materialist encyclopaedia in fragments. Again, although I will start with an *exposition* of dialectical materialism, my aim is not to contribute to scholarly discussions *on* dialectical materialism. My focus is on the *how* and *now*,

[1] The term "dialectical materialism" was coined by Joseph Dietzgen in *Das Wesen der menschlichen Kopfarbeit* [The nature of human brainwork] as a form of dialectics which allegedly superseded Hegel's version, which had become "reactionary" (Dietzgen, 1869/1961), – Georgi Plekhanov and Karl Kautsky are often mentioned as early adopters of the term.

H. Zwart, *Continental Philosophy of Technoscience*, Philosophy of Engineering and Technology 38, https://doi.org/10.1007/978-3-030-84570-4_3

and my aim is to explore how to *practice* dialectical materialism of technoscience today (cf. Žižek, 2014/2015, p. 1; Hamza, 2016, p. 163).

The precise relationship between Hegel's dialectics and dialectical materialism (Marxist dialectics) is a controversial issue. Marx and Engels famously presented their collaborative oeuvre as an *Umstülpung* (reversal or inversion) of Hegel's dialectic. They saw history not as the self-realisation of ideas, but as driven by material and socio-economic factors, so that consciousness ("*Bewusstsein*") is determined by socio-economics existence ("*Sein*"). In his *Epilogue* to *Capital* (Volume I), Marx indicates that, for Hegel, thinking functioned as the "demiurge" of reality, so that the real world was seen as a phenomenological realisation of primal ideas (1867/1979b, p. 27). His own version of dialectics, Marx argues, entails a demystification of Hegelian dialectics. Yet, dialectics as such remains the point of departure, if only because, as Marx phrases it, Hegel's idealistic inclinations by no means prevented him from presenting dialectics in a remarkably comprehensive and conscious manner (p. 27), giving rise to a philosophy which is inherently critical and revolutionary, even anticipating bourgeois society's inevitable negation and decline (p. 28). Still, dialectical idealism has to be transformed ("umstülpen", p. 27) into a more scientific version (dialectical materialism), which sees consciousness (ethical ideals, religious views, legal norms, etc.) as a psychic *translation* (p. 27) of material, socio-economic conditions.

This immense undertaking of reversing Hegelian dialectics into (what later came to be known as) dialectical materialism, while at the same time bringing dialectics on a par with contemporary developments during the second half of the nineteenth century, remained unfinished (notwithstanding the 44 volumes of writing which Marx and Engels managed to produce). This basically means that dialectical materialism should not be seen as a complete whole, but as a *program for research*, i.e. as an unfinished, organic body of textual materials, awaiting further development and elaboration by new generations of scholars. This also applies to Hegel's own oeuvre, of course, for notwithstanding the fact that Hegel presented his thinking as an encyclopaedic system, his oeuvre is evidently "work in progress". Hegel's death interrupted an (interminable) process of continuous revisions and expansions.

Thus, the collaborative oeuvre of Marx and Engels is both a continuation and a subversion of Hegel's paradigmatic effort, both critical of and dependent on Hegel. Hegel's philosophy of history was replaced by "historical materialism", while Hegel's rudimentary reflections on labour, political economy and the role of machines (e.g. in the *Philosophy of Right* as well as in some early manuscripts written in Jena) dramatically expanded into Marx's impressive political-economical volumes. While Engels' *Dialectics of Nature* sublated (i.e. both leaned on and updated) Hegel's *Philosophy of Nature*, the *Anti-Dühring* (in combination with multiple other texts on various topics) may be regarded as fragments of a dialectical materialist version of Hegel's *Encyclopaedia*.

Engels was a remarkably prolific writer. Besides journalism, political pamphlets and an (astonishingly extensive) correspondence, his publications and manuscripts cover a broad spectrum of fields, in accordance with his encyclopaedic mindset: from the humanities (German literary studies, linguistics, language studies and philology, philosophy and philosophical criticism, palaeoanthropology, ancient history, medieval history, military history, modern history, theology and early Christianity) via the social sciences (sociology, economy, geography, cultural anthropology, legal studies, gender studies, parapsychology) up to the natural sciences (mathematics, physics, chemistry, biology and ecology). What all dialecticians (Aristotle, Aquinas, Hegel, Marx, Engels, etc.) have in common is that they see their work not as a specific discipline, but as a *Gesamtwissenschaft*. Marx and Engels aspired to achieve what Aristotle managed to bring about in Ancient Greece and Hegel in Germany. Seen from this perspective, Engels's kaleidoscopic output can indeed be considered as building blocks for an unfinished dialectical materialist encyclopaedia, addressing and assessing all existing research fields.

On the other hand, while Hegel's *Logic* was a substantial part of his oeuvre (consisting of two versions, spread over three volumes), it is precisely this part which seems underdeveloped in the writings of Marx and Engels. Louis Althusser has argued that, fully absorbed in his political-economical and historical materialist writings, Marx never managed to produce a dialectic (or *Logic*) of his own. And this is a problem notably because Marx and Engels never fully developed their methodology, although their way of working is evident in their writings. When it comes to *practicing dialectical materialism today*, we may follow and extrapolate their examples, but without the guidance that would have been provided by a logical or methodological manual. Marx and Engels develop their methodology *along the way*, and we must familiarise ourselves with it by reading their work, preferably all of it.

Although Marx and Engels continued to read an discuss "old Hegel", notably his *Logic* (as indicated in their correspondence), Marx himself never found or took the time to write a Marxist version of Hegel's *Logic*, Althusser argues, although the outlines of a Marxist philosophical practice are nonetheless available. According to Althusser, they can notably be found in the prefaces and epilogues accompanying Marx's major scientific publications, such as *Contribution to the Critique of Political Economy* (published in 1859) and *Capital,* Volume I (published in 1867). These textual materials can be said to contain Marx's "discourse on method", albeit in a fragmented manner. Below, these documents (fragments of a dialectical materialist "logic") are listed:

- Karl Marx (1859/1961a): *Vorwort* (Preface) – Zur Kritik der politischen Ökonomie (*A Contribution to the Critique of Political Economy*) – published 1859 [Karl Marx – Friedrich Engels – Werke Band 13, pp. 7–14]
- Karl Marx (1857/1961, 1939/1983): *Einleitung* (Introduction) – Zur Kritik der politischen Ökonomie (*A Contribution to the Critique of Political Economy*)/*Grundrisse der Kritik er politischen Ökonomie* (Foundations of the Critique of Political Economy) – written in 1857, published posthumously [Karl Marx – Friedrich Engels – Werke Band 13, pp. 615–644; Karl Marx – Friedrich Engels – Werke Band 42, pp. 19–45]

- Karl Marx (1867/1979a): *Vorwort* (Preface) – Das Kapital: Kritik der Politischen Ökonomie, Erster Band (*Capital: a Critique of Political Economy, Volume I*) – published in 1867 (Karl Marx – Friedrich Engels – Werke Band 23, pp. 11–17)
- Karl Marx (1867/1979b): *Nachwort zur zweiten Auflage* (Epilogue) – Das Kapital (*Capital*) – published in 1867 (Karl Marx – Friedrich Engels – Werke Band 23, pp. 18–28).
- Friedrich Engels (1893/1977): *Vorwort* (Preface) – Das Kapital: Kritik der Politischen Ökonomie, Zweiter Band (*Capital: a Critique of Political Economy, Volume II*) – published in 1893 (Karl Marx – Friedrich Engels – Werke Band 24, pp. 7–27).

Thus, the *Umstülpung* of Hegel's dialectics also means that what had remained underdeveloped in Hegel (e.g. political economy) was significantly expanded by Marx and Engels and what was substantially developed by Hegel (e.g. his *Logic*) was left unfinished or was pushed into the margins in the writings of Marx and Engels. For a quick comparative analysis (a comparative anatomy) of their oeuvres, the following table may serve as outline:

Hegelian dialectics →	**Dialectical materialism** (*Umstülpung*)
Philosophy of history →	Historical materialism
Logic →	Prefaces and epilogues
Philosophy of nature →	Dialectics of nature (Engels)
Philosophy of right →	Political economy (Marx)
Encyclopaedia →	Anti-Dühring and multiple additional fragments on various topics (notably Engels)

Thus, although in the case of Marx and Engels a *Logic* (outlining the dialectical method) is only marginally present, their methodology can nonetheless be extracted from their work, especially from these satellite documents, indicating a rupture with Hegel while at the same time providing a methodological bridge between Hegelian dialectics (Hegel's method) and dialectical materialism (Marxism as a methodological research practice). This method of Marx and Engels, moreover, is not frozen into a rigid protocol, but remains a vibrant program and practice of research, something to be further developed *along the way*. The fragments listed above can be considered as a Marxist "discourse on method", providing a first indication as to how dialectical materialism can be practiced today. Special attention will be given to the question how to extrapolate this method into a dialectics of technoscience.

Fragments on Method

In his *Preface* to the first edition of *Das Kapital*, Marx explicitly compares his research in political economy with life sciences research. In both cases, Marx argues, the organic whole (e.g. society at large, or the biological organism as such) proves a more readily accessible target of inquiry than the basic components (commodities and living cells, respectively). Therefore, the physiology of living bodies precedes the biochemistry and microscopic anatomy of living cells, – in accordance, we could add, with Hegel's syllogism, which likewise progresses from the general, i.e. organisms (M_1) via the particular (differentiated components: M_2) to the concrete cell (M_3). In other words, Marx draws an analogy between social formations and organisms (the general) as well as between commodities and cells (the concrete; Marx, 1867/1979a, p. 12). Research starts with life or society in general (e.g. the social organism), while the biological cell, as a focus of technoscience, is already a *product* of technoscientific activity, never a given.

Moreover, Marx argues that, whereas scientists conduct laboratory experiments under particular (controlled) circumstances, with the help of optical instruments or chemical agents (studying phenomena in their "normality", that is: undisturbed by fluctuating circumstances, p. 12), political economy (the study of the evolution of socio-economic formations) can better be compared to natural history. Both fields of research adopt a systemic perspective, studying society outdoors under real life circumstances (in Manchester or London for instance). In other words, political economy, as it had developed when Marx began his research, was comparable to natural history as it had developed in the nineteenth century, before the scientific revolution transformed it into biology as real, laboratory science (cell physiology, microbiology, experimental research etc.). The scientific approach adopted by Marx focusses on basic components (commodities), comparable to cell physiology in biology. Again, we notice how closely Marx follows Hegel's dialectical syllogism, indicating how the focus of research shifts from the general (natural history as an empirical field) via the particular (laboratory research) towards the concrete (commodities, cells).

In the *Epilogue* to the second edition of *Capital* (Volume I), Marx returns to the issue of method, pointing out that his method has been poorly understood (1867/1979b; p. 25). Dialectics is a rigorous science, he claims, demonstrating how human consciousness ("*Bewusstsein*") is determined by socio-economics existence ("*Sein*"), rather than vice versa. Dialectics is the systematic study of the origin, existence, development and decline of social formations (as "social organisms"). In other words, the development of a comprehensive view is not the starting point (as in traditional metaphysics) but the result, while the understanding of the *phenomena* of consciousness requires a thorough grasp of (what could be referred to as) the *noumenal* dimension, the dynamics of microscopic components (in political economics: the dialectics of commodities).

Capital (Volume I) is presented as the continuation (p. 11) of *Contribution to the Critique of Political Economy*, published in 1859 (the year in which Darwin published his *On the Origin of Species*). In his *Preface* to this preparatory volume (sometimes referred to as "*Capital, Volume Zero*"), Marx (1859/1961) likewise describes his method as a socio-economic "anatomy" (p. 8) of modern society. Marx also explains how, after migrating to London in 1850, the British Museum provided him with the perfect observatory or platform: a perfect vantage-point from where to observe and analyse bourgeois society in a systematic manner, focussing on particular disruptive events, such as the discovery of gold in California, Australia and Alaska (1859/1961, p. 10). Rather than functioning as an observatory in the empirical sense, however, the British Museum provided him with an enormous amount of written materials assembled there, which he subjected to his "symptomatic" reading practice, as Althusser would later phrase it, focussing on the gaps and contradictions: on the unsaid. Marx also again explains how Hegelian dialectics is subjected to a reversal by emphasising that consciousness ("*Bewusstsein*") is determined by our mode of being ("*Sein*"), by the evolving modes of production. A particular social formation originates and thrives, until it exhausts the material conditions of its own existence. Moreover, humanity inevitably sets itself only such tasks as it is able to solve, and certain problems arise only when the material conditions for their solution are already present.

It is tempting to apply these insights to technoscientific research, i.e. to contemporary processes of knowledge production. From a Marxist perspective, scientific discourse is determined by the *modes* of knowledge production: the social organisation or research, the technologies in place, rather than vice versa, while normal discourse addresses those question that are solvable under existing conditions, in principle at least, until the existing mode of knowledge production has effectively exhausted its own resources. In that case, a scientific crisis is inevitable, until the outdated and inhibiting mode of knowledge production is replaced by a new technoscientific regime. Also, science commences with a critical analysis of existing discourse (M_1), whose latent tensions and contradiction provide an impetus to critical inquiry, a process of *Zerlegung* (M_2), eventually giving rise to a set of validated concepts (M_3), enabling the development of a *scientific* approach.

Another core text for understanding the methodology of Marxism is the (initially retracted and posthumously published) *Introduction* to Marx's *Contribution to the Critique of Political Economy*, which also serves as introduction to the *Grundrisse*, dating from the same period. As a result, two versions of this *Introduction* were incorporated in the *Marx Engels Werke*: one in volume 13 (1857/1961) and one in volume 42 (1939/1983). In this *Introduction*, Marx (1857/1961, 1939/1983) points out how bourgeois political economy is grounded in a mythology of origins, considering individual (entrepreneurial) hunters and gatherers as point of departure. For Marx, this is the political economy version of the Robinsonade: a bourgeois literary motif (also recognisable in the history of technoscience, as the myth of the lone scientific genius, working in splendid isolation, or in the image of the technoscientific entrepreneur, entitled to appropriate the results of what in reality stems from collective efforts). The gestalt of the modern autonomous individual – the *outcome* or product, genealogically speaking, of a long and extended socio-economic history – is mistaken for its starting point. In pre-historic societies, individuals were dependent rather than independent, and rural communists rather than bourgeois entrepreneurs. Since time immemorial, production and reproduction were collective endeavours.

Moreover, Marx presents the coming-into-being of human society as a dialectical process: a dialectic of production and consumption (1939/1983, p. 25 ff.). Production commences a process that is finalised by consumption as its end, while both are mediated by distribution and exchange. In other words, Marx argues, production and consumption constitute a *syllogism*, in the Hegelian sense of the term: interconnecting the *general* form of production (A) via *particular* forms of distribution and exchange (B) with *concrete* instances of consumption (E). Moreover, it entails an interpenetration of opposites, in the sense that production is also consumption, and consumption also production. Production is consumption ("productive consumption") because it consumes its resources and wears out its means of production. And consumption is also production in the sense that the consumption of food, for instance, produces and sustains life. In production, the producers objectify themselves, while in consumption the product becomes personified. Production reaches its end in consumption so that, without consumption, there would be no production. Dialectically speaking, consumption *produces* production. It is only in consumption that the product really becomes a product, while consumption drives the development of new products. Consumers produce these products, provoke them into existence, by subjectively envisioning and practically consuming them. On the other hand, no consumption without production, so that the mode of consumption is determined by the mode of production. Indeed, the production process generates its own consumers. This is a telling example of how Marx continues to employ the basic logic of Hegelian dialectics: production inevitably passing over into consumption as its opposite, and vice versa, while at the same time materialising it (connecting it with the material conditions of human existence).

The third part of the *Introduction* presents an outline of Marx's method (1939/1983, p. 34 ff.). Two pathways are open to us, Marx argues, two methods in the literal, etymological sense. The first pathway ("*der erste Weg*", p. 35, 632) is the one adopted by mainstream political economists. They start from something general, a living totality (e.g. the population inhabiting a particular country) and set to work to analyse it in terms of categories and concepts. The method of science, however, moves in the opposite direction, backwards as it were, and this is the way of thinking ("Weg des Denkens", p. 35, 632), from concepts to the real. Scientific research for Marx is an *appropriation* of the real. Thus, a syllogism emerges. Marx's method begins as discourse analysis: subjecting established discourse (as source material) to a procedure known as symptomatic reading, focussing on the "symptoms", i.e. the contradictions, and resulting in a set of critical concepts. With the help of these concepts, Marx sets out to analyse real processes of production, circulation and consumption. While Hegel conceives the real as a product of ideas, Marx sees modes of knowledge production as materialisations of ideas, which subsequently appropriate and process the real. This, according to Marx, is the method (the pathway) of thinking.

Before zooming in on Friedrich Engels' effort to develop a full-fledged materialist dialectics of nature, I will first present an example of what a Marxist view on technoscience amounts to, namely by discussing the history of astronomy written by Anton Pannekoek (1951/1961), a prominent practicing astronomer, but also a prominent Marxist.

Anton Pannekoek: A Marxist View on the History of Astronomy

My first concrete exposition of a dialectical materialist approach to technoscience starts at the beginning as it were, highlighting the research field to which Hegel devoted his doctoral dissertation in Jena (entitled *De Orbitis Planetarum*), namely astronomy. Marxist scientists were active in life sciences research (Bernal, Haldane, etc.) but in astronomy as well, and Anton Pannekoek (1873–1960) is a telling example, as a prominent practicing astronomer who was also a prominent Marxist. As an astronomer, he studied the statistical distribution of stars in the Milky Way and became founding director of the *Anton Pannekoek Institute for Astronomy* (Tai, 2017; Tai et al., 2019). As a Marxist, he was an international representative of council communism and author of several books and brochures. Finally, in 1951, he authored a history of astronomy as a research field (Pannekoek, 1951/1961). From the 1910s onwards, he kept his socialist activities and his scientific career at a distance, and even ended up writing two separate autobiographies: one focusing on his involvement in the communist movement, the other discussing his scientific research (Pannekoek, 1982; Tai et al., 2019, p. 9). Thus, his astronomical publications on the one hand and his Marxist publications on the other evolved as two parallel series (as if written by two different authors, apparently quite independent from each other). In fact, his oeuvre is a syllogism. Initially, both Marxism and astronomy were part of his efforts to come to terms with the real in a rational manner, building on the conviction that both the natural and the social real are rational. Subsequently, astronomy and Marxism evolved as separate oeuvres, carefully segregated from one another. Finally, however, both strands of writing converged into his history of astronomy, written towards the end of his life and published in 1951, wherein the duality is finally sublated. In Pannekoek's *History*, astronomy is presented as the first science, not only in the chronological sense of the term, but also in the sense that astronomy grounds and reflects the way we conceive the world as such.

From the outset Pannekoek emphasises how astronomy ("Bewusstsein") is connected with modes of production and ways of living ("Sein"). His *History* begins with the astronomy of Polynesian ocean travellers, for whom astronomy provided a celestial compass on their remarkable journeys across the Pacific, until their autochthonous (indigenous) knowledge fell victim to what is currently known as "epistemicide": the systematic eradication of non-Western knowledge systems, as a result of their contact with Western imperialism. This confirms the dialectical view that knowledge never begins with a blank slate (to be filled with observations: "induction"), nor as a Robinsonade. Rather, astronomy begins as appropriation and elimination, with *loss* of knowledge, as existing knowledge practices are exposed to the negativity of a new set of principles, a new relentless logic, supported by a socio-economic power regime.

Subsequently, Pannekoek describes the early history of astronomy as a collision (a battlefield) between nomad knowledge and agricultural knowledge. He explains that, whereas nomads were primarily focussed on the moon (employing moon calendars as a first astronomical moment), agricultural societies are oriented towards the sun, and therefore bent to produce solar calendars. This resulted in the first big challenge of astronomy: how to *overcome* the incompatibility of moon and solar calendars, a *real disparity*, as Žižek (2016/2019) would later call it. This disparity cannot be completely solved and continues to leave its symptomatic traces in calendars even today. The result was a calendar dominated by the solar principle, but incorporating the lunar cycle as a sublated moment. Astronomy (i.e. the production of reliable calendars) initially developed as a priestly science, and observance of celestial phenomena was considered a religious vocation. The calendar was the result of the movements of two celestial deities, a diurnal and a nocturnal one. Thus, as Pannekoek points out, astronomy developed in close interaction with socio-economic conditions, e.g. the dominance of agriculture as a result of the Neolithic Revolution (1951/1961, p. 31).

Agriculture gave rise to large-scale political entities (kingdoms), moreover, so that another function became increasingly important, namely the apparent correlation between earthly and celestial phenomena. Palace politics and policies of expansion resulted in a need to foresee the future, an ability to read the omens, in preparation of large enterprises. Thus, Assyrian astrology emerged, considering celestial phenomena as signs, conveying decipherable messages. Science, Pannekoek argues, is fostered by practical human activity (p. 85) and he discards the opposite idea, namely that science evolves from leisure (as a privilege of the elite stratum). Although Plato's astronomic insights, for instance, can indeed be regarded as an expression of the mode of thinking of the Athenian elite, who ruled over large numbers of artisans and slaves, this actually proved an epistemological obstacle, because these Athenian masters looked down upon manual work with utter disdain, as something dishonourable (p. 101), which was precisely the main reason why exact experimental natural sciences never developed in antiquity. Platonic astronomy involved a conscious withdrawal from practical experience, resulting in the idea of the universe as a perfect globe where only circular motion is admissible. Aristotle, who emphasised the importance of careful observation, deviated from this trend, and Hellenistic astronomy, practiced in Alexandria, already relied on the use instruments, allowing Eratosthenes to determine the size of the earth with the help of a gnomon (a practical instrument, a vertical stick casting a measurable shadow). Whereas in Assyria and Babylon astrology had been the privilege of monarchs, in the Roman Empire, horoscopes became democratised and were adopted by virtually everybody as a decision-making tool. Subsequently, during the medieval period, Arabian astronomy produced astronomical instruments of great artistic skill, again primarily designed for practical astrological purposes.

In occidental modernity, instruments evolving from concrete practice likewise played a decisive role, Pannekoek argues. The scientific revolution, which began in astronomy, resulted from the development of new technical instruments produced in workshops by artisans, such as the cross-staff and the telescope. The ancient (Platonic) conviction that the world is *spherical* (the first moment as it were), was still very much alive in the work of Copernicus, but was now challenged by technology-based observation. Pure (withdrawn, detached) reason refuses to accept irregularities, but anomalies and contradictions quickly began to accumulate (the second moment). For astronomical computing, Greek and Roman number systems proved highly impracticable (and not only for making astronomical calculations, but also for other arithmetic practices such as book-keeping). This obstacle was superseded by the introduction of Arabic numbers in combination with other computational tools such as logarithmic scales (John Napier) and decimal fractions (Simon Stevin). Modern astronomy (M_3) resulted from this combination of precise observation and advanced computation.

Tycho Brahe's work exemplified the importance of measuring instruments, resulting in his pupil Kepler's insight that the orbit of planets is elliptic: the third moment, dialectically speaking, restoring mathematical harmony and order (after the logic of circular movement had been negated), and converging advanced artisanal contrivances with advanced mathematics. Thus, dialectically speaking, the solar system represents a concrete reconciliation of mathematical order and empirical evidence on a higher level of complexity, through a combination of technical, observational and computational skills.

The fabrication and systematic use of instruments such as quadrants and sextants became a condition sine qua non for producing accurate, computationable data. At the same time, astronomy was highly dependent on the "benevolence" (i.e. financial support) of monarchs and princes, who provided funding for developing the necessary infra-structure, as exemplified by Tycho Brahe's Uraniborg observatory: a fascinating early modern example of the drive towards scientific upscaling (Uraniborg = the city of Urania, the Muse of astronomy). The monarch expected something in return, however: a confirmation of the heavens as a harmonious whole, a celestial template which the sublunary, political world ought to mimic, revolving around the monarch (*le soleil, c'est moi*). But the monarch also expected something else, namely prognostications. God did not create His heavenly scenery without a purpose, and the celestial machine was a wonderful device, available for consultation, providing a political compass. In a famous illustration we see Tycho Brahe as a homunculus inside his observatory, handling his contrivances. Paradoxically, he was the last of the naked-eye astronomers and refused to use a telescope. This praise for the human eye as a "perfect" organ was perhaps a desperate attempt to preserve his autonomy, a refusal to become a mere accessory of this giant machine (exemplifying the machinery of absolutism).

Gradually, however, scientists increased their independence by fabricating their own tools and by conducting experiments with self-made contrivances, as in the case of Christiaan Huygens, who was quite dexterous, not only in building accurate pendulums, but also in grinding lenses for telescopes (cf. Aldersey-Williams, 2020), while Newton constructed a metallic mirror. Menial workmanship became a crucial requirement for constructing and optimising astronomical equipment. Together with clocks, telescopes and other instruments, the calculus was developed as a computational tool. These developments gave rise to the mechanical view of the universe: the solar system as a rotating machine (exemplifying the mechanical machine as the concrete universal of modern thinking).

The industrial revolution unleashed a rapid advance of precision technology, thereby transforming astronomy from a pursuit practiced by individuals into a collective, large-scale enterprise. Capitalism produced ingenious precision machines, and Pannekoek explicitly mentions the Carl-Zeiss Werke in Jena, for instance, as an industrial producer of high-precision equipment. The rise of big industry created the technical basis for a rapid expansion, not only of capitalism as such, but also of astronomy, where astronomers became highly skilled brain workers. Every instrument is made twice, Pannekoek argues, by two different types of brain workers, the first time in an industrial setting, but subsequently also by practicing astronomers themselves, who continuously have to optimise and improve their means of knowledge production (p. 325). The initial, standardised apparatus (M_1) is challenges and affected by particular outdoors circumstances (M_2) and optimised / adapted by practitioners (M_3).

The ideal of a harmonious cosmos gave way to a new ideal, namely that of extremely precise measurement, through optimised instruments and rigid working methods. This ideal inevitably encountered challenges, however. Every time extreme accuracy seemed to be within reach, new frustrations emerged in the form of deviations, irregularities and fluctuations caused by unknown sources of error. Eventually, the most important source of error proved to be human observers themselves. Thus, an important *experience* emerged. On closer inspection, *every* human observer is in error, and with increased training, personal error does not become smaller, it only becomes more constant. Research inescapably suffers from systematic error, caused by various sources of variation, including atmospheric diffraction. Although machines were designed in such a way that the role and influence of individual observers was marginalised, the crisis was also addressed in a different manner, namely through the invention of statistics. Rather than trying to eliminate the error completely, the *inevitability of error* was *incorporated into* the methodology of measurement as such (i.e. sublated), as a containable component, namely by calculating averages of large numbers of equivalent measurements made by large numbers of observers, so that, at a higher level of comprehension, sufficient accuracy could be attained, and deviations could be superseded. It also implied that science became a *collective* enterprise, conducted by professional research teams employed at big observatories. Big machines gave rise to big science, involving large numbers of trained researchers producing masses of observational data. Industrial machines combined great size with detailed precision, and human observers became homunculi as it were, positioned inside huge steel mammoth machines, directing the motions of such machines merely by pressing buttons. Indeed, electronic control of gigantic instruments became the material basis of modern astronomy (p. 338).

In the final chapters of his *History*, Pannekoek describes another dialectical process, namely the convergence of astronomy and astrophysics, i.e. a new form of science which studies the world of elementary particles both at a very small and at an immensely large scale, thereby opening up the noumenal dimension of stars and atoms, of energy and matter. The focus shifts from how heavenly phenomena appear to the eye towards their composition and structure in terms of subatomic particles and nuclear radiation (the noumenal dimension). Initially, stars and planets had been regarded as deities, as animated "luminaries". In early modern science (the second moment), celestial bodies were seen from a deterministic perspective, as lifeless passive "objects", whose movements were completely determined by external forces and factors. An ontological divide was introduced, between inorganic and organic nature, as stars, planets and comets were considered lifeless and inorganic. From a dialectical perspective, such an opposition, such a binary mode of thinking (living versus non-living, organic versus inorganic, phenomenal versus noumenal, etc.) is unsustainable in the end. Hegel already raised the question when and how chemical processes become life and for Pannekoek this also applied to the chemistry of stars and other celestial entities such as nebulae. In the early twentieth century, the convergence of astronomy and astrophysics resulted in an evolutionary conception of the universe. Stars are alive: they are born, evolve and age. Both stellar objects and living organisms are part of the great universal cycle of transformation of matter and energy, of growth and decay, or positive and negative entropy, i.e. the Hegelian concept of a cycle of cycles. Research into the inner, noumenal, subatomic constitution of stars revealed their life-history (p. 494), which is not endless repetition, but evolutionary development of stellar individuals and species. Life is progressive change, from the primary substance of primal matter (protons) up to the macro-molecules of earthly life.[2] In short, for astronomers and astrophysicists, all the world is energy, in the dialectical sense of ἐνέργεια: continuous motion, activity, growth and change. Whereas for Kant as a bourgeois thinker mind and spirit are considered as separate realms (Pannekoek, 1901), dialectics reveals that the methods of natural science can be applied to human history as well, seeing the world as a constellation of processes, rather than things. This is exactly the core problematic of Friedrich Engels' dialectics of nature.

Friedrich Engels and the Technoscientific Reproducibility of Life

As a result of their division of labour, while Marx focussed on the social sciences (political economy), Friedrich Engels developed his dialectical assessment of technoscience in treatises such as *Anti-Dühring* and *Dialectics of Nature*, resulting from

[2] This line of thinking was taken up by another dialectical thinker, Teilhard de Chardin (Chap. 7).

his fascination with the natural sciences, in combination with his resurging interest in the work of "old Hegel".

According to Engels, the three most important revolutionary developments in nineteenth-century science were (a) thermodynamics, (b) the theory of evolution and (c) the physiology of the cell. Rather than specific research topics, these three breakthroughs entailed a comprehensive dialectical view on nature. Thermodynamics addresses the relationship between energy, movement and force, seeing nature as ἐνέργεια, as being-at-work, with energy transforming from one form into another, eventually giving rise to the concept of entropy and its negation: "negative entropy", i.e. life (the tendency to develop and maintain high levels of complexity and to resist disorder for extended periods of time). Evolution entails the idea of an inherent conflict within every living entity (e.g. between nature and nurture, genome and environment, sensitivity and immunisation, between adaptation to and modification of the environment, etc.), giving momentum to growth and development (Duran-Novoa et al., 2011; Vincent, 2016). Dialectics is the philosophy of how evolution operates, and evolution theory is itself a dialectical phenomenon: a research program which continues to develop (spiralling between gradualism and catastrophism, quantitative and qualitative change), resulting a comprehensive understanding of the origin and future of life. Last but not least, cell research addressed the basic metabolism of life as such, because the cell is the basic structural and functional unit of all organisms, the *concrete universal* of life, so that cell research culminates in the question "What is life?"

Against this backdrop, Engels became especially interested in what he saw as the molecular (noumenal) essence of life, namely proteins or, more specifically, albumin (*Eiweiß*), seeing life as the mode of existence of living substances. I will begin with a short recap of Hegelian dialectics, focussing on those aspects that are most crucial for developing a dialectical materialist understanding of contemporary technoscience. Subsequently, the outlines of a dialectical materialist understanding of technoscience as a research practice will be fleshed out, building on Engels, but also on later (scientific) authors who were inspired by his writings, e.g. life scientists such as Haldane, Needham and Bernal. Next, I will consider the criticism raised against Engels's dialectics by some twentieth-century Marxists. And finally, I will flesh out a dialectical diagnostic of contemporary technoscience, shifting the focus from artificial albumin as "living matter" (as *discussed* by Engels) to contemporary research on synthetic cells (as *anticipated* by Engels). Engels' view on the technoscientific reproducibility of life will therefore serve as case material for practicing dialectics of technoscience today.

Dialectics of Science and Nature as a Research Program

Friedrich Engels developed his dialectics of science and nature in his correspondence with Karl Marx, but more systematically in his *Anti-Dühring* (1878/1962) and in *Dialectics of Nature* (1925/1962a), a collection of notes and manuscripts which he left unfinished. Dialectics, for Engels, is the science of the laws of motion and development of nature, society and thought (1878/1962, p. 11, 132). The Marx-Engels correspondence (1983) served as a dialectical laboratory where important scientific developments were quite regularly discussed. These epistolary exchanges addressed a broad range of scientific topics, from Justus von Liebig's and James Johnston's work on organic and agricultural chemistry via Darwin's *The Origin of Species* up to John Tyndall's experiments on light scattering.

Engels began his dialectical analyses of science in the late 1850s, building in the work of Hegel. In a letter to Karl Marx (July 14, 1858), he announces his intention to reread Hegel to find out to what extent the latter anticipated recent progress made in the natural sciences, notably in physiology (e.g. cell biology) and chemistry. In this letter, Engels already outlines how he sees the cell as the Hegelian being-in-itself and the living organism as the realisation of the "idea" of life, while comparative physiology demonstrates how quantitative changes give rise to qualitative leaps (Marx & Engels, 1983 II, p. 326). Unfortunately, Engels' extensive research efforts were significantly hampered by competing time-consuming activities, not only his professional work at the offices of Ermen & Engels in Manchester, but also the posthumous editing of Volumes II and III of Marx' *Capital* (Hunt, 2009). The question addressed in this chapter is, to what extent Engels's dialectical views are still relevant for addressing recent developments in contemporary technoscience. My objective is to update dialectical materialism by raising a question comparable to the one addressed by Engels in the nineteenth century, namely: how to assess contemporary technoscience from a dialectical perspective? What would a dialectics of contemporary life sciences research amount to? How to *practice* dialectics of science and nature *today*?

Engels's dialectics of science and nature (as a research program) resulted in four core texts:

- *Dialectics of nature*, a collection of manuscripts written between 1876 and 1878 and published posthumously in 1925 (Engels, 1925/1962a)
- The Marxist classic *The Anti-Dühring* (*Herrn Eugen Dührings Umwälzung der Wissenschaft*) dating from the same period, written between 1876 and 1878 and published in 1878, after having been serialised in the German socialist periodical *Vorwärts* (Engels, 1878/1962).
- *Socialism: utopian and scientific* (*Die Entwicklung des Sozialismus von der Utopie zur Wissenschaft*), first published in 1880 and based on excerpts from the Anti-Dühring (Engels, 1880/1962).
- *Ludwig Feuerbach and the End of Classical German Philosophy*, written 1886 and published the same year (Engels, 1886/1962).

These documents reflect at least two over-arching trends in Engels's scholarly activities. First of all, his return to and resurging interest in the work of "old Hegel",[3] the

[3] A phrase used by Marx and Engels in their correspondence, cf. Engels's letter to Marx of December 3, 1851 and Marx's letters to Engels of August 19, 1965 and March 25, 1868 (Marx &

philosophical hero of his youth, from the late 1850s onwards, a development which concurred with a similar "return to Hegel" in Marx.[4] Secondly, a growing interest in the quickly progressing natural sciences,[5] an interest which he, again, shared with Marx during this same period, although whereas the latter predominantly focussed on fields such as agricultural chemistry (Justus von Liebig, James Johnston, Henry Carey) and mathematics (as reflected by his extensive notebooks on differential calculus),[6] Engels mainly occupied himself with physics, (organic and inorganic) chemistry and biology.[7]

In the writings listed above, Engels aspired to come to terms with what he considered as the three decisive scientific discoveries of the nineteenth century (Engels, 1886/1962, p. 294), namely: (a) the discovery of the laws of thermodynamics (conservation of energy and increase of entropy); (b) the theory of evolution; and (c) the discovery of the structure and function of the cell. All three discoveries revolve around the question of life, as we have seen. The cell is the basic structural unit of living entities: the prototypical realisation of the idea of life as such. As to thermodynamics, one could argue that, dialectically speaking, whilst the first law represents conservation as the *first* dialectical moment (M_1), which is *negated* by entropy (conceived as *negativity*, i.e. as the *second* dialectical moment, M_2), then life (more concretely: a microbe or a living cell) represents the *negation of the negation*: the third dialectical moment (M_3). Indeed, life is "negative entropy", as Erwin Schrödinger phrased it (Schrödinger, 1944/1967; cf. Zwart, 2013) to capture the astonishing ability of living systems to maintain and reproduce high levels of complexity, and to withstand environmental entropic pressures for extended periods of time. Finally, the theory of evolution represents the *historical* dimension of life, urging us to see life as something which is perpetually in flux and continuously changing.

In the context of these research activities, Engels devoted special attention to what he saw as the molecular or *noumenal* essence of life, namely proteins or, more

---

Engels, 1983 I, p. 292; II, p. 289; IV, p. 34). Also in his letter to Albert Lange (29.3.1865) Engels confesses his "deep feeling of piety and devotion for the titanic old fellow".

[4] See for instance Marx & Engels, 1983 II, p. 275, 326. Marx used Hegel's dialectical logic as a scaffold for designing the structure of *Das Kapital* (Marx & Engels, 1983 III, 393–402; Arthur, 2004).

[5] In his correspondence with Engels, Marx underscored the socio-economic importance of the scientific work of, for instance, Humphry Davy and Justus von Liebig (cf. Bernal, 1936).

[6] Hegel was already dissatisfied with the conceptual vagueness of the calculus. Are differentials *dy, dx* finite quantities, are they zero, do they represent an intermediate state between being and nothing, so that vanishing is their truth? This vagueness symptomatically reflects the tension between the continuous and the discrete, between physical movement and mathematical symbols. Differentials seemed chimeric, minimal magnitudes, caught at the moment of their disappearance. The impact of Marx's work was limited due his insufficient awareness of the developments concerning the calculus in the nineteenth century (Kennedy, 1977).

[7] Engels intensely acquainted himself with the natural science after stepping down from commerce and moving from Manchester to London, where he went through process of re-education in mathematics and natural science: a thorough scientific "moulting" ("Mauserung", 1878/1962, p. 11; Hunt, 2009, p. 288). An important influence was the "red" chemist Carl Schorlemmer (1879), a close friend of both Marx and Engels (Benfey & Travis, 1992).

specifically, albumin (*Eiweiß*). As will be discussed in more detail below, Engels basically saw life as the mode of existence of proteins. Whereas abiotic, inorganic entities are damaged and destroyed by entropic metabolism, in living entities metabolism is incorporated and transformed into sustainable biochemical processes. Engels' thoughts about proteins and cells evidently built on Hegel's philosophy of nature, notably the latter's dialectical analysis of the chemical process (Hegel, 1830/1986, § 326 Z, p. 292; § 335 Z, p. 333) where he argues that the chemical process is an analogue of life in the sense that, if the chemical process would continue spontaneously, it would be life.[8] Indeed, there is a glimpse of vitality in the chemical process (Hegel, 1830/1986, § 335 Z; Ferrini, 2011, p. 208), but contrary to inorganic chemical processes, which do not renew or reproduce themselves on their own accord, Hegel argues, life is a self-renewing chemical process made perennial.

Last but not least, Engels already predicted that, one day, scientists will be able to produce proteins artificially (*in vitro*) in their laboratories. And if they succeed in doing so, he argued, these artificial proteins will undoubtedly exhibit the phenomena of life (e.g. organic metabolism), however weak and short-lived these may be.[9] In other words, Engels anticipated (on various occasions) the creation of artificial life in the laboratory as the inevitably "end" (dialectically speaking) of modern biochemical research.

Precisely this latter development is currently evolving from "utopia" to "science", as Engels once phrased it (1880/1962). For indeed, at this very moment, scientific research consortia are trying to build synthetic cells in man-made laboratories. As a (dialectically inspired) philosopher of science, I myself happen to be actively involved (as a principal investigator) in one of these projects, namely the BaSyC project, an acronym which stands for *Building a Synthetic Cell*.[10] As indicated above, the question addressed in this chapter is, to what extent Engels's dialectical views are still relevant today, notably for philosophers who aim to come to terms with the conceptual implications and socio-cultural consequences of synthetic cell research, as a high-profile, trans-disciplinary and cutting-edge area of inquiry (Zwart 2017). I intend to revivify dialectical materialism as a philosophical methodology by raising a question comparable to the one addressed by Engels in the nineteenth century, namely: how to assess contemporary cell research from a dialectical perspective? What would a dialectical assessment of contemporary life sciences research amount to? How to *practice* dialectics of science and nature *today*?

[8] "Der chemische Prozess ist so ein Analogon des Lebens. Könnte er sich durch sich selbst fortsetzen, so wäre er das Leben; daher liegt es nahe, des Leben chemisch zu fassen" (Hegel, 1830/1986, § 326 Z, p. 292); "Wenn die Produkte des chemischen Prozesses selbst wieder die Tätigkeit anfingen, so wären sie das Leben. Das Leben ist insofern ein perennierend gemachter chemischer Prozess" (§ 335, p. 333).

[9] "Wenn es je gelingt, Eiweißkörper chemisch darzustellen, so werden sie unbedingt Lebenserscheinungen zeigen, Stoffwechsel vollziehen, wenn auch noch so schwach und kurzlebig" (Engels, 1925/1962a, p. 560).

[10] http://www.basyc.nl

Assessing the relevance of Engels's writings for contemporary philosophy of technoscience proves a challenging issue, first of all because his "dialectics of nature" became a highly controversial endeavour, especially within Marxist discourse itself (Sheehan, 1985/2017; Kangal, 2019). A relatively large number of Marxist scholars explicitly dismissed it, often favouring a Mach-like or neo-Kantian approach to science instead. Therefore, the multiple controversies raised by Engels' writings up to this day cannot be ignored.[11] Moreover, Engels developed and published his ideas during the 1870s and 1880s, and the life sciences evidently experienced a series of dramatic revolutionary transitions since then. Therefore, rather than "applying" Engels' views, these sections will amount to an exercise in *extrapolation*. Although I will start with the question how Engels himself used dialectics to analyse scientific research concerning the phenomena of life during his own era, the core question will be the one already brought forward above, namely: how to be a dialectical philosopher of natural science or technoscience *today*? What would a contemporary dialectics of nature, focussing on synthetic cells (as a symptomatic case study, reflecting broader technoscientific trends) amount to?

The structure of the remainder of this chapter is as follows. I will begin with a short recapitulation of Hegelian dialectics, focussing on those aspects that are most crucial for developing a dialectical materialist understanding of contemporary technoscience. Subsequently, the outlines of a dialectical materialist understanding of technoscience as a research practice will be fleshed out, building on Engels, but also on later (scientific) authors who were inspired by his writings, e.g. life scientists such as Haldane and Bernal. Next, I will consider the criticism raised against Engels' dialectics by some twentieth century Marxists. And finally, I will flesh out a dialectical diagnostic of contemporary technoscience, shifting the focus from artificial albumin as "living matter" (as *discussed* by Engels) to contemporary research on synthetic cells (as *anticipated* by Engels).

[11] "Engels was at the root of whatever was wrong with Marxism. With few exceptions, the argument against Engels had now become a virtual orthodoxy, perhaps best summarised in Norman Levine's *The Tragic Deception: Marx contra Engels* (1957)" (Rees, 1994). Besides the many Marxist authors who vehemently criticised Engels, there are many others who systematically ignore him. In Slavoj *Žižek's Less than nothing: Hegel and the shadow of dialectical materialism* (2012/2013), for instance, Engels is not even mentioned, while in *Absolute recoil: towards a new foundation of dialectical materialism*, his name appears only once, in a quotation borrowed from Lenin (Žižek, 2014/2015, p. 1), although some phrases may implicitly refer to Engels, such as the remark that the idea of a tension or contradiction between Hegel's dialectical method and Hegel's system – discussed below – is "ridiculous" (2012/2013, p. 195). Supporters of Engels (Bernal, Haldane, Levins and Lewontin, etc.) often have a scientific background. Rather than "applying" dialectics to physics or biology, they adopted dialectics as their scientific method, acknowledging that science is inherently dialectical (Royle, 2014).

Engels' Dialectical Materialist Rereading of Hegel

As Hegel explains in the Introduction (*Einführung*) of his *Phenomenology of the Spirit* (Hegel, 1807/1986): whereas the sciences study natural phenomena (natural processes and entities), thereby developing a (fragmented and partial) phenomenology of nature, philosophy is the science of science: a *phenomenology of scientific experiences*. Hegel develops a systematic and comprehensive perspective on nature by discerning a dialectical unfolding in the interactions of scientific subjects (researchers) with their scientific objects (natural processes and entities). As explained in Chap. 2, while science is about knowing or understanding natural objects, philosophy aims to understand the process of knowing as such. It is a critical assessment of the ways in which particular forms of knowledge, emerging at particular moments in history, allow nature to reveal itself. Dialectics is the systematic exposition of scientific research practices as they appear on the scene, tracing the journey of consciousness passing through various configurations or stations of knowledge towards more comprehensive forms of understanding. Thus, dialectics entails *knowing about knowing*: a phenomenology of scientific experience.

Dialectically speaking, moreover, science (as a methodological, self-critical endeavour aspiring to come to terms with nature) is inherently dialectical, even if practicing scientists themselves are not always aware of this, because it relentlessly challenges, contradicts and eliminates its own results, in order to reach a more comprehensive level of understanding. Science is never satisfied with its own outcomes. It is a zealous, unhalting process which finds no satisfaction in existing forms of knowledge but is driven by an inherent unrest, continuously disturbing and spoiling its own satisfaction: a relentless drive to move farther. Existing science is rational, certainly, but this does not mean that scientists are already there, for what is rational about science is first and foremost the scientific method. Dialectically speaking, science is not a collection of facts and insights, but a *process*, a practical endeavour, a *praxis*, whose actual results will only remain temporarily valid. Even the most robust insights will be challenged sooner or later by new findings, – spurred on by technological innovations, as Engels will later emphasise. Science progresses through stages and, although all these stages are necessary and inevitable as such, none of them is final. From a dialectical perspective, scientific knowledge production is a process of becoming, continuously unfolding. All existing knowledge forms will evaporate sooner or later, but the rationality and necessity of this (seemingly haphazard) dynamics can be dialectically grasped.

At the same time, dialectics acknowledges a stabilising tendency in science, namely the tendency to integrate multiple partial knowledge fragments into a coherent, encyclopaedical *system.* Therefore, two apparently juxtaposed dimensions can be discerned: on the one hand the drive towards a theoretical processing and systematic assembling of available research results, and on the other hand the impetus (no less forceful) to challenge, negate, overcome and defreeze these integrative efforts, seeing current knowledge systems as temporary episodes. This tension is also discernible in the edifice of Hegel's own oeuvre (Engels, 1886/1962), which on the one hand strives to develop a comprehensive and encyclopaedic *system* of knowledge (the "conservative" dimension) while this system is at the same time challenged and negated by the dialectic *method* itself (the "progressive" dimension).

Whereas the scientific revolution continues to unfold, outdated insights become spectres and sediments of knowledge, as living science continues to progress farther. Sooner or later, all forms of knowledge will be negated, sublated and transformed. As Engels phrases it, dialectics is not only a phenomenology, but also a "palaeontology" of knowledge (1886/1962, p. 269), seeing the present as the temporal outcome of a long history,[12] about to give way to newly emerging and proliferating landscapes of research. The Hegelian claim that "*all* that is *real* is *rational"* applies to science insofar as existing theories are exemplifications of the scientific method. Yet, sooner or later, their validity will be undermined, they will be exposed as misguided, or only partially reasonable, and therefore unreal (bound to become mere history). Indeed, *all* that comes to be, deserves to perish wretchedly (Engels, 1886/1962, p. 267), as Mephistopheles already proclaimed, and this also applies to science. For Engels, even Hegel's own impressive encyclopaedic system was but a temporary edifice. Sooner or later, it will become a monument of the past, while science as a dialectical praxis continues to unfold, by overcoming the next crisis.

Dialectics is a method of thinking which starts from the awareness that *thinking itself* is subject to a process of becoming. This evidently also applies to dialectics, so that the dialectical method is not a static, but a dynamical procedure which must continuously be refined and transformed. By implication, Engels's version of dialectics, although building on Hegel, at the same time aims to transform and enhance it, to assure that dialectics remains up to its task of effectively addressing the challenges of the dawning era. This requires a thorough understanding of Hegel's thinking, for dialectical materialism is a transformation *from within*. The force of dialectics consists precisely in this creative tension or interaction between the system-building trend (the systematic effort to preserve existing knowledge fragments by developing them it into a consistent, comprehensive view) and the dialectical method (the awareness that this edifice of knowledge itself is constantly under pressure and besieged by emerging disruptive developments).

Hegel's prediction about the end of philosophy was correct, Engels argues, in the sense that modern science will indeed abolish philosophy. Philosophy must and will resurge, however, albeit no longer as a separate field (practiced at a safe distance from the turmoil of active scientific research), but as philosophy *in* science, sublated by and preserved as an *inherent* self-reflective dimension of the scientific enterprise (1878/1962, p. 129). Philosophers should be self-consciously *there* where science happens.[13] For Engels, philosophy is a dialectical and critical reflection on the dynamics of scientific research as such. If we see traditional philosophical

[12] Cf. Hegel: "Vor der Wissenschaft liegt der reiche Inhalt, den Jahrhunderte und Jahrtausende der erkennenden Tätigkeit vor sich gebracht haben" (1830/1986, p. 28)

[13] Cf. Hegel: "Das Prinzip der Erfahrung enthält die unendlich wichtige Bestimmung, dass … der Mensch selbst dabei sein müsse… Er muss selbst dabei sein … mit seinem wesentlichen Selbstbewusstsein" (1830/1986, § 7, p. 49).

contemplation as the first moment of the knowledge production process (M_1), which was negated, disrupted and marginalised ("dethroned") by modern scientific research (M_2), the end result will be a negation of the negation: a resurgence of philosophical reflection, but now as an inherent dimension of scientific praxis (M_3). The science-philosophy divide will become sublated, allowing philosophy to become more relevant and up-to-date, while science becomes more comprehensive and advanced (cf. Bernal, 1937). Our current world-view materialises in technoscientific research, while research feeds and transforms our emerging worldview.

This is also the basic message conveyed by Hegel's dialectic of Master and Servant as we have seen. The Master (initially in control) represents philosophy-as-contemplation, producing abstract *universal* knowledge, in contrast with the hands-on experiences of the Servant. Eventually, however, the practical knowledge concerning *particular* aspects of nature produced by Servants (in an interactive, experimental manner, through research-as-praxis) will prove much more powerful and effective than the lofty contemplations of the Master who, instead of transforming nature, develops a more passive form of contemplation: a worldview. Thus, the initial supremacy of the Master will by subverted by the practical and transformative know-how of the Servant, who actively puts an end to his "bondage" ("Knechtschaft") via epistemic emancipation (Engels, 1925/1962a, p. 480). Dialectically speaking, empirical science represents the emancipation of the labouring Servant vis-à-vis abstract contemplation (as a privileged but unworldly form of *otium*). Servants explore and interact with nature more directly, through their experimental work, developing powerful tools to effectively manipulate *concrete* natural objects, both inside and outside their laboratories. In terms of Hegel's logic, this development reflects the dialectical unfolding from abstract universal knowledge (*das Allgemeine*, A), via experimental exploration of particular aspects of nature (*das Besondere*, B), towards the creation and modification of concrete entities (*Einzelheit*, E), as materialisations of the technoscientific approach to life.

Dialectics of Science and Nature

As indicated, Engels's aim was to update Hegelian dialectics by focussing on the practical and material aspects of technoscientific research. The dialectics of science and nature which results from this, still builds on Hegelian dialectics, whose great merit had been to see the world (natural, historical as well as intellectual) as a process.[14] Yet, in contrast to Hegel, dialectical materialism stresses the hands-on, interactive dimension of human thinking, the *technicity* of science, up to the point of acknowledging that science inevitably evolves into *technoscience*, – even though he doesn't literally use this term. In Engels's writings on scientific inquiry, there is a

[14] Engels explicitly praises "Hegels System, worin zum ersten Mal – und das ist sein großes Verdienst – die ganze natürliche, geschichtliche und geistige Welt als ein Prozess [begriffen wird]" (1880/1962, p. 206).

consistent emphasis on experimental praxis and on the disclosing and transformative role of scientific and industrial contrivances and instruments.[15]

Dialectical materialism endorses Hegel's claim that the laws of dialectics not only apply to technoscience, but also to nature as such. The natural sciences are inherently dialectical because dialectics represents the *subjective* analogue of the *objective* dialectics at work in nature (Engels, 1925/1962a, p. 331; cf. Schweiger, 2011, p. 28). In other words, dialectics applies both to the subject pole (technoscience) and to the object pole (nature) of the knowledge production process. At the subject pole, the emphasis is on technoscientific research as a form of *labour* (Lefèvre, 2005), as a technological *praxis* as we have seen, highly dependent on advanced *means of knowledge production* such as microscopes, telescopes and spectroscopes. At the object pole, the emphasis is on movement, as life itself evolves via conflict and contradiction towards higher levels of complexity. Science continuously develops: gradually, but also via dramatic leaps (when quantitative accumulative growth enables qualitative change and disruptive transition). Motion is the mode of existence of matter in general and of living matter in particular, and this applies both to chronic motion (metabolism) and to diachronic motion (evolution).

Engels' most famous work in this area is the Marxist classic *Anti-Dühring* (1878/1962). As Engels himself points out, what began as a polemical essay quickly evolved into an extended "positive" (p. 6, 8) exposition of the dialectical method, applying it not only to history and economics, but also to science and nature. The *science* pole and the *nature* pole (the subject and the object pole) should not be seen as compartmentalised from each other, but rather as inevitably *interpenetrating* each other, for while science allows the natural world to appear in a certain manner, the objects of research challenge researchers to develop their contrivances and approaches in a certain direction.

In 1877, in a letter to Franz Wiede, Engels wrote that, as soon as he had finished with criticising Dühring, he would concentrate all his energies on a larger work that he had planned for years, in order to demonstrate that the laws of dialectics apply both to human society and to nature (Griese & Pawelzig, 1986). This immense project combined a rereading of Hegel with an intensive journey of exploration through the evolving natural sciences, both theoretically and practically (e.g. in chemical industry), resulting in a thorough intellectual "moulting". Engels worked on it from 1873 up to 1882, resulting in almost 200 textual fragments and addressing three key issues from a dialectical perspective: the dialectical *history* of the natural sciences, the dialectical *logic* of scientific inquiry, and a criticism of one-sided (i.e. undialectical) scientific positions. Thus, he aimed to overcome both bourgeois metaphysics

[15] This evidently contradicts the views of Lukács who proclaimed that "Engels' deepest misunderstanding consists in his belief that the behaviour of industry and scientific experiment constitutes praxis in the dialectical, philosophical sense. In fact, scientific experiment is contemplation at its purest" (1923/1971, p. 132). Due to lack of proximity, Lukács misunderstands the basic logic of experimental laboratory research, a practice which, as Claude Bernard explains, combines theoretical contemplation (θεωρία) with hands-on, manual modification (πρᾶξις): in laboratory practice "il serait impossible de séparer ces deux choses: la tête et la main" (Bernard, 1966, p. 27).

(thinking in terms of dichotomies, e.g. humans versus nature, mind versus matter, etc.) and scientific empiricism (i.e. the neglect of theoretical thinking), and to replace it with a dialectical approach, emphasising the continuous interaction between science and society, theory and practice, experiments and reflection, heredity and environment, etc. and the alternation of quantitative (evolutionary) and qualitative (revolutionary) change.

As Hegel already argued, dialectical laws can be discerned both in scientific experiences concerning nature (the subject-pole of the knowledge production process) and in nature as such (the object pole, where countless instances of contradiction and sublation can be pointed out). The chemical process as such, for instance, is an inherently dialectical process (Hegel, 1830/1986, § 326 ff.; 1831/1986). Basically, Engels aims to demonstrate that scientific research is an *inherently dialectical* endeavour that will significantly benefit from the *conscious* and *systematic* application of dialectical insights and methods. His aim was to save dialectics by rescuing it from the constraints of bourgeois idealism, transporting it to the realm of natural science instead (1878/1962, p. 10). Dialectics will allow science to emancipate itself: from the dogmas of traditional metaphysics (frozen into scientific concepts), but also from the scientific tendency towards fragmentation and empiricism, at the expense of genuine insight (1878/1962, p. 14).

According to Engels, again explicitly building on Hegel, three basic dialectical laws can be distinguished (1925/1962a, p. 348): (a) the law of the transformation of quantity into quality and *vice versa*; (b) the law of the interpenetration of opposites; and (c) the law of the negation of the negation. Engels' exemplifications of the first law are borrowed directly from Hegel's work. Increasing or decreasing the temperature of water, for instance, is an incremental, quantitative change, Engels explains, until a point is reached at which water suddenly becomes transformed into steam or ice: a qualitative transition (1878/1962, p. 118). Another example he often uses are carbon compounds, where the addition of elementary components (C, H, O) to a particular compound will bring about qualitative change (p. 119). Whilst a certain amount of carbon dioxide is a necessity for life, too much of it transforms it into a poison, and so on.

As to the second law, multiple examples have already been given, such as the interaction between subject and object. Natural science is a relentless productive interaction between science and nature. Technological research practices allow natural objects to emerge, while the object of research (say, a living cell) determines the tools, approaches, mind-set and intentionality of the laboratory subject. Another example is the opposition between heredity and environment (between nature and nurture). Dialectically speaking, it would be one-sided to understand living organisms solely in terms of heredity or genetics (claiming that organisms *are* their DNA, their genomes), but it would likewise be one-sided to see them solely as products of their environment (claiming that organisms *are* the product of environmental factors).[16] Rather, life results from the constant interaction and interpenetration of

[16] The latter position would later (quite un-dialectically) be defended by Trofim Lysenko.

both dimensions (heredity and adaptation). Likewise, in chemistry, analysis and synthesis are often regarded as opposites (as processes moving in juxtaposed directions) but in actual laboratory practice, the one is highly dependent on the other, as synthesis (recombination) presupposes analysis (*Zerlegung*) and vice versa.

Also the third dialectical principle (the negation of the negation) was discussed earlier. A dialectical process starts from an initial situation or first moment (M_1), for instance: the rural communism practiced by self-sufficient villages in the pre-industrial past (Engels, 1880/1962, p. 2015). As Marx explained in *Capital*, the rise of capitalism obliterated this rural world, so that farmers were expropriated and forced to migrate into urban areas as battle zones, where a Darwinian struggle for existence raged (Engels, 1880/1962, p. 216): a process which represented the second moment, of negativity and disruption (M_2). It involved, among other things, a separation (estrangement) of production and consumption, as food products were no longer produced collectively by consumers themselves (in villages), but in factories, as commodities, so that consumers from now on had to buy these food products (e.g. industrially produced bread, beer, canned meat, etc.) on the market (Zwart, 2000). Traditional agricultural and artisanal know-how was replaced by scientific knowledge (mathematics, chemistry, logistics, human resource management, etc.) to rationalise and increase the pace and scale of the food production process. Yet, although industrial production *seems* rational, it actually results in anarchy and contradictions (e.g. highly competitive food markets, environmental pollution, waste, social disruption, etc.). Therefore, a third moment (the negation of the negation) becomes inevitable (M_3), which will amount to an expropriation of the expropriators (Engels, 1878/1962, p. 124): the confiscation of the means of production by the working classes and consumers. Scientific knowledge will no longer be the property of the owners (the bourgeoisie), but common knowledge, freely accessible and consciously employed to optimise the agricultural system in terms of equity and sustainability.

A similar dialectics is discernible in nature as such, however. According to Engels, the whole of geology is a series of negated negations (1878/1962, p. 127), as mountain ranges emerge in response to strains in the earth crust, resulting in increased weathering and accumulation of sediments, resulting in new strains etc. (cf. Bernal, 1936; Royle, 2014). But we may also use the development of natural organisms as example, say: a plant. The seed containing the program of life (the "concept" of life; "heredity", M_1) is exposed to a hazardous, entropic environment (the vegetative version of the trauma of birth) which threatens to negate and eliminate this fragile life form (M_2), unless the plant manages to *use* this threatening environment as a resource for growth and protection (the *negation of the negation*), thus growing into an adult form, as the concrete realisation of the *idea*, so that two antagonistic forces (nature and nurture, heredity and environment) are reconciled, functioning complementary to each other. Living entities *need* this dramatic interaction between both components (heredity and environment, nature and nurture) to flourish and thrive. Indeed: they basically *are* (the product of) this interaction.

From Bourgeois Metaphysics to Dialectics of Science

From a dialectical perspective, Engels argues, Hegel must be credited for having developed the dialectical method, understanding both the natural and the cultural world as processes of becoming (1878/1926, p. 22), but he also remained an idealist (p. 23), envisioning history (including the history of science) primarily as a dialectical unfolding of *ideas* which realise themselves in the course of time, in the form of episodes or stages, challenging, negating and sublating each other. In contrast to Hegel, dialectical materialism emphasises that thinking (*Bewusstsein*) is determined by being (*Sein*; Engels, 1878/1962, p. 25). This means that scientific convictions and ideas are shaped *in interaction with* nature, under specific socio-economic conditions, in the context of actual research practices in laboratories and industries. Scientific ideas emerge in particular historical settings: they reflect and materialise the *technicity* of science, i.e. the *means of knowledge production* developed to enable researchers to effectively address practical challenges. Science is a praxis, and scientific research means *practicing* science. It is hard work, involving both intellectual and menial components (both brain-work and active manipulation). The industrial revolution owes much to science, but the reverse is also true: science (notably chemistry) owes much to the industrial revolution and thrived because of it (cf. Lefèvre, 2005). Engels points to the connection between thermodynamics and the use of steam engines, for instance, while telescopes were initially developed for military purposes, but he also sees mathematics as grounded in concrete human activities and bodily practices. For him, mathematics is the product of a long history of active engagement with nature (1878/1962, p. 36). It is only in bourgeois metaphysics that mathematics is conceived as something pure, axiomatic and abstract, so that the idea arises that a line is a point moving through empty space (p. 37), ignoring the grounding of mathematical theory in geodesy and other earthly pursuits. Even mathematical terms like "body" (used for three-dimensional forms, e.g. cube, sphere, etc.) etymologically imply materiality and physicality (p. 38), while the calculus allowed scientists to study processes of continuous change experimentally. It is no coincidence of course that "laboratory" literally means workshop, a locality designed for fabricating knowledge (Zwart, 2019b).

Modern science means: understanding by doing, reflecting a shift (in the history of knowledge) from hands-off (aristocratic) contemplation to hands-on (interactive) experimentation. Bourgeois ideology, however, is hampered by a split consciousness (*Zerrissenheit*), because it separates practical innovation ("applied research") from "pure" science (the science version of aesthetic disinterestedness, of *l'art pour l'art*). This split is connected with a whole series of similar compartmentalisations (between science and society, basic and applied research, intellectual and menial activities, etc.). From a dialectical materialist perspective, however, labour (the use and development of technologies and machines) is a necessary precondition for producing scientific knowledge claims, even allegedly "pure" ones. This already applies to Aristotle, Engels argues, a thoroughly dialectical thinker (1880/1962, p. 202) who combined philosophical speculation with natural history and anatomy (discovery by doing). Although bourgeois consciousness tends to underestimate the importance of (what is denigratingly referred to as) the Middle-Ages, it was during the (late) medieval period that the first industries were created and the first machines were produced, while new instruments became available for experimentation (Engels, 1886/1962, p. 279; 1925/1962a, p. 457, 462), resulting in the collaboration of monastic scholarship and craftmanship (notably instrument making, cf. Pannekoek, 1951/1961; Zilsel, 2003). Moreover, whereas the early modern era (when the bourgeoisie still represented a progressive factor) was a period of revolutionary fervour,[17] during the seventeenth and eighteenth centuries many bourgeois thinkers opted for lofty ("disinterested") contemplation rather than hands-on experimentation, so that in the eighteenth century, genuine dialectical works typically emerged outside philosophy proper (in the writings of Diderot and Rousseau for instance, 1880/1962, p. 202) while it was only in the nineteenth century that the first truly scientific laboratories were created (by Justus von Liebig and others). Bourgeois thinking tends to see nature as a collection of separate entities (things), rather than as a systemic, dynamic and evolving process (p. 203). The question whether something is alive, for instance, is not a matter of Yes or No, Engels argues, for living and dying are complex, protracted processes, so that metaphysical, scientific or legal attempts to discern a clear caesura between the two are bound to falter (p. 204).

The emphasis on praxis not only applies to the context of discovery, but also to the context of validation and justification, moreover. For Engels, the ultimate proof of the validity of knowledge is provided when we are not only able to understand and predict, but also to actively manage, reproduce and recreate natural processes in our laboratories and industries (Engels, 1925/1962a, p. 497). The artificial, technological reproduction of natural processes *in vitro* is the ultimate test of the validity of scientific theories. Rather than positing a divide between thinking and being, or between theory and practice, the starting point of dialectical materialism is the unity of theory and praxis brought about by experimentation, putting theories to the test experimentally, and further developing them through experimental trials. Indeed, conducting an experiment means using nature to put our concepts to the test, revealing how nature itself likewise unfolds in accordance with dialectical patterns.[18] Science is not a body of knowledge, but first and foremost a practical endeavour, a systematic interaction with the unfolding environment. The subject and the object pole of the knowledge production system interpenetrate each other via the means of knowledge production: scientific instruments handled by scientists which allow the

[17] Again, Engels discerns a dialectical process here: the medieval period sets in with the fall of Rome and the elevation of Constantinople (M_1), but is itself eliminated/negated during the fall of Constantinople (the moment of negativity: M_2) which, paradoxically perhaps, unleashes a return to Greek philosophy and science in Western Europe: the Renaissance as negation of the negation (M_3).

[18] "Die Natur ist die Probe auf die Dialektik, und wir müssen es der modernen Naturwissenschaft nachsagen, dass sie für diese Probe äußerst reichliches, sich täglich häufendes Material geliefert und damit bewiesen hat, dass es in der Natur, in letzter Instanz, dialektisch hergeht … dass sie eine wirkliche Geschichte durchmacht" (1878/1926, p. 22; 1880/1962, p. 205).

world to appear in a certain manner, as modifiable molecules and organisms for instance, and this allows researchers to produce *reproducible* knowledge. From a dialectical materialist perspective, there is no divide but rather continuity between laboratories and factories, as well as between universities and industries, and the concept of pure knowledge is a bourgeois fiction. Even logical categories do not exist as pure axiomatic mental entities but rather as ideas that realise and optimise themselves in practice.

Whereas bourgeois metaphysics is imprisoned in mental activities (thinking, consciousness, ego-centric meditations, the mind-body problem), the technicity of technoscience opens up the noumenal dimension of nature: the basic molecular processes of life, energy and matter. And contrary to what bourgeois authors (including Eugen Dühring) claim, thinking is not something we do as individuals. Rather, for Engels, thinking relies on what nowadays would be referred to as distributed intelligence: it is a collective activity involving millions of individuals, dispersed through space and time (Engels, 1878/1962, p. 80). Constricted ideas produced by single, isolated individuals should be regarded with critical suspicion. At the subject pole, dialectics studies the dialectical unfolding of research programs, which inevitably constitutes a tale of tensions, anomalies and contradictions, where existing knowledge systems (displaying the tendency to freeze into certain modes of thinking), are disrupted and pushed forward by the development of even more powerful and precise machines, whose ground-breaking discoveries may enforce dramatic revisions of dominant ideas (Engels, 1878/1962, p. 82). And at the object pole, dialectics allows us to see nature not as a series of chance events, but as processes in which dialectical laws are at work and dialectical patterns can be discerned (Engels, 1878/1926, p. 11).

Contrary to the splendid isolation propagated by bourgeois metaphysics, Engels contends, philosophy should no longer be considered a separate field standing apart from science (1878/1962, p. 24; 1880/1962, p. 207). Rather, philosophy should be practiced as an integrated endeavour. "Pure" philosophy has become irrelevant and futile. The end of (bourgeois) philosophy is at the same time a new beginning, however. Similar to how social philosophy should be practiced in close connection with political activity, the philosophy of science and nature should likewise be practiced in close interaction with actual research endeavours, fostering the further development of the dialectical method. Philosophy of science should become philosophy *in* science, using the dialectical method to bring the dynamics of scientific progress to the fore. And again, modern science is not only a dialectical process itself, but also reveals the dialectical logic inherent in the natural processes it studies.

Dialectically speaking, three moments can be distinguished in the history of thinking. During the initial situation (M_1, exemplified by Plato and others), philosophy was seen as contemplation, far removed from practical interaction with nature. This is reflected in the Platonic view of nature as perfectly harmonious and balanced, a view which must have been quite at odds with the experiences of artisanal and agricultural labourers of ancient societies, working hard to mould and domesticate nature in a hands-on manner (Zwart, 2009). During the scientific and industrial revolutions of the nineteenth century, however, philosophy seemed to be *negated* (dethroned and marginalised) by science and technology (M_2). As a third moment, dialectics represents a reconciliation in the sense that it reveals how science unfolds in a dialectical manner by disclosing the dialectical processes at work in nature. The opposition between science and philosophy is sublated as dialectical materialism becomes dedicated to the task of revealing and critically assessing the metaphysics that is unconsciously at work in scientific research. And this reconciliation represents the dialectical "end" of a long history of estrangement (Engels, 1878/1926, p. 14).

In ancient Greece (M_1), many Greek thinkers already were materialists and dialecticians (1878/1926, p. 14) and even in modern history many examples of "spontaneous" dialecticians can be found.[19] Overall, however, bourgeois metaphysics[20] (represented for instance by British idealism, e.g. Berkeley, Hume, etc.) tended towards negating materialism and dialectics (M_2). The existence of an external material world was put into question by idealism and solipsism, while nature was seen as completely deterministic: a world in which nothing (nothing spontaneous or unpredictable) could ever happen. Moreover, bourgeois thinking posited a series of insurmountable divides, between subject (the ego of solipsism) and object (the thing-in-itself), between society and nature, between *is* and *ought*, between fact and value, between social science and natural science, etc. This position is now itself negated by dialectical materialism, which represents a return of materialism, not in the ancient contemplative sense, but informed by two millennia of research (1878/1962, p. 129), including the most recent and advanced scientific insights. This dialectical negation of the negation (M_3) will transcend the dichotomies of bourgeois metaphysics, resulting in a reconciliation, of social science and natural science for instance, so that scientists become conscious of the social dimension of their research as a decidedly *social* practice.[21] Dialectics is itself a science: it is philosophy in the form of a science. Its vocation is to consciously develop the dialectical method, but in dialogue and interaction with scientific research practices: discerning, articulating and addressing the dialectical processes at work *in* science.

A similar view was developed by British Marxist Christopher Caudwell (1939/2017), who saw the cleavage between theory and practice (between basic and applied research) as the signature characteristic of "bourgeois" epistemology: ceasing to be interested in matter, while becoming exclusively concerned with the mind

[19] Engels mentions Jean-Jacques Rousseau, for instance (1878/1926, p. 19), who posits an original natural position (M_1) which is negated by the estrangement of modern society (M_2), but bound to resurge on a higher level of social complexity in a future society where the opposition between nature and culture is sublated (M_3).

[20] This label refers to a mode of thinking which sees the world in terms of dichotomies and opposites, e.g. subject versus object, society versus nature, *is* versus *ought*, etc., and in terms of fixed, separate things (or even things-in-themselves) rather than in terms of processes of relentless interactive change.

[21] Cf. Bernal (1937): in contrast with determinism, dialectical materialism explains the emergence of radical new things in nature, such as life and human society, while at the same time showing how science is part of social and historical development, also as a source for generating scientific questions, fostering scientific innovation and discovery.

and with subjective, phenomenal reality (1939/2017, p. 30), while science, on the other hand, became increasingly impersonal. According to Caudwell, during the bourgeois period, while technoscientific practice became increasingly specialised and empirical, theory became increasingly abstract and diffuse, resulting in an amalgam of reductionism and mysticism. Under the sway of bourgeois thinking, while physicists concentrated on matter, philosophers were exclusively concerned with the mind. Thus, the subject-object relationship became the most pressing problem of bourgeois philosophy, closely related to the question whether the external, material world exists at all. Both the object and the subject were stripped of their qualities. The subject vanished (only phenomena and experience existed, p. 63), while the object became the unknowable thing-in-itself, ceasing to exist. This philosophy of contemplation became increasingly estranged from the working masses who actively worked with machines (either in laboratories or in industries). Philosophy lacked the experience of active interaction and struggle with material objectivity, so that philosophy became a marginalised theoretical reserve. Subjectivity likewise eroded as the observer (as a concrete subject) became eliminated (p. 46). Dialectical materialism, Caudwell argued, must supersede bourgeois thinking by rediscovering both the subject (as a brain-worker, operating machines) and the noumenal object (made accessible via technological advances), so that philosophical consciousness becomes restored to activity.

For Engels, this effort to supersede bourgeois metaphysics was part of a historical unfolding which affected both the subject and the object pole of the knowledge production process. As to the object pole: during the initial situation, in ancient Greece (M_1), the focus was on nature in general, on being as a whole, on abstract, general, universal ideas about nature (*Allgemeinheit*, A; Hegel, 1830/1986, p. 57). This holistic view was negated by the *negativity* of modern empirical science (M_2), which amounted to a breaking down, an analysis (*Zerlegung*) of natural phenomena into *particular* components (*Besonderheit*, B). The negation of the negation (M_3), entails a return to the whole in the form of a *systemic* and converging approach, but now on a higher level of comprehension and understanding, focussing on concrete entities which exemplify nature or life as such, e.g. the cell (*Einzelheit*, E). Thus, initial general insights inevitably give way to divergence and contradiction (*Entzweiung*), but these are sublated by a third moment, a return (*Zurückführung*) to concrete convergence (*Einigkeit*) (Hegel, 1830/1986, p. 88).

Dialectical Materialism Versus Bourgeois Epistemology in Twentieth Century Marxism

From the 1920s onwards, Engels's dialectics of science and nature became a controversial endeavour and Engels's project has remained the target of substantial polemics ever since, notably in Marxist circles, and notably among authors who aim to restore "pure" Marxism by cleansing it of what they see as contaminations. The dialectics of nature debate was ignited by prominent authors such as György Lukács and Jean-Paul Sartre[22] (Sheehan, 1985/2017; Sim, 2000, p. 132; Kangal, 2019) and eventually became a "polemical battlefield" (Kangal, 2019), giving rise to a whole "mountain of literature" (Sheehan, 1985/2017, p. 54). Notably Lukács aimed to discredit "the banalities of Engels's version of dialectical materialism" (Feenberg, 2017, p. 111), limiting the dialectical method "to social issues, while leaving the natural scientists to carry on as before" (p. 120). Lukács and his followers saw the very idea of a dialectics of nature as mistaken, stemming from a "retreat to Hegel", and allegedly in "opposition" to Marx (Lukács, 1978, p. 110).[23] According to Lukács, "the misunderstandings that arise from Engels' account of dialectics can in the main be put down to the fact that Engels – following Hegel's mistaken lead – extended the dialectical method to apply also to nature" (1923/1971, p. 24). Dialectics of nature was allegedly "non-Marxian", he and others maintained (Burman, 2018).

These efforts to posit a cesura between Marx and Engels are contradicted by a juxtaposed strand of publications, less visible and less vocal perhaps, but based on a more careful reading I would argue, which emphasise continuity between Marx and Engels, notwithstanding their "division of labour" (i.e. Marx's decision to focus on political economy), both with regard to their intense rereading of Hegel and concerning the endorsement of a dialectics of nature. Both in his writings (including *Capital*) and in his correspondence with Engels, Marx stated his conviction that dialectics, including Hegel's discovery of the law of transformation from quantitative into qualitative change, is attested by history and the natural sciences alike (cf. Marx's letter to Engels, 22 June 1867; MECW 42, p. 385; Stanley, 1991; Griese & Pawelzig, 1995), while in *Capital* he refers to chemistry, for instance, to explain dialectics.[24] While there is no evidence that Marx disagreed with Engels's project, there is plenty of evidence to the contrary (Royle, 2014; Hundt, 2014; Blackledge, 2017). The claim that Marx "did not share" Engels' interest in the natural sciences (Thomas, 2008, p. 1) is evidently mistaken, and the suggestion that Marx (unlike Engels) would adhere to endorsing a humanity vs. nature dualism is misguided,

---

[22] On December 7, 1961, Jean-Paul Sartre participated in a famous debate in Paris before a large audience (Sartre et al., 1962) to criticize Engels and defend the thesis that the laws of dialectics only apply to mental and social processes, so that there can be no such thing as a dialectics of nature. In *Critique of Dialectical Reason*, however, Sartre had argued that organisms negate their negations, and develop dialectically, by rejecting and excreting the disruptive forms of negativity which they themselves engender. Sartre here defines need as the negation of the negation (overcoming the lack which hampers to organism to function), pointing out that also other animals besides humans develop tools to overcome that which opposes their project of integration (Sartre, 1960/2004, p. 83, 85).

[23] In Volume 3 of *The Ontology of Social Being*, however (his unpublished Nachlass as it were), Lukács reconsiders his position, now praising Aristotle's, Hegel's and Engels' dialectical understanding of labour (Lukács, 1980).

[24] Already in his thesis, Marx practiced what he consistently preached, as his thesis already amounted to a close dialectical reading of ancient Greek atomism and a dialectical interpretation of the declination of the atom (Stanley, 1989).

since Marx (like Engels) consistently emphasises the interaction and metabolism between both. And yet, as Kangal phrases it, no other work has been subject to as much conflict and chaos in Marxist scholarship than Engels' *Dialectics of Nature*. It is not my purpose to present a full overview of this debate, of course, but I cannot wholly ignore it either. A dialectical materialist perspective on *contemporary* science must position itself against this turbulent backdrop. Therefore, a concise resume of this debate will be presented, albeit from a dialectical materialist position. As a starting point of the debate, I will use the Marxist classic *Materialism and Empiriocriticism* published by W.I Lenin, a staunch supporter of Engels, in 1908 (Lenin, 1908/1979).

In *Materialism and Empiriocriticism*, Lenin aims to update Engels's dialectics of nature through a polemical review of the theories of Ernst Mach, Richard Avenarius and other "empiriocriticists" (Lenin, 1908/1979). In terms of style and structure, Lenin's book echoes Engels' polemical review of Eugen Dühring's work (1878/1962). The empiriocriticists where progressive authors who aimed to develop a new epistemology (a new theory of human understanding) to replace pre-scientific, "metaphysical" conceptions with science-compatible ones, but Lenin's purpose is to demonstrate that they were much less progressive than they thought, because they actually articulated a bourgeois epistemology.

Empiriocriticists regard "sense data" (i.e. impressions, observations, sensations, affections and the like) as the primary starting point of human knowledge and reject the materialistic ("metaphysical") idea that these impressions are produced in us by material things existing in the outside world, independent of human consciousness. There is *nothing* beyond experience, they argue, no environment without a subject who experiences it. By positing the existence of things beyond sensation, materialism gives rise to an unnecessary duplication ("Verdopplung") of the world (p. 13). The material world posited by materialism is discarded as a mystification. According to Lenin, however, by regarding objectivity as a mere product of human subjectivity (by considering the world as a product of human consciousness), these empiriocriticists "plagiarise" (p. 35) the views of eighteenth-century bourgeois idealist George Berkeley, who already denied the existence of an outside world, considering it an illusion and claiming that *being* equals *being-perceived (Esse est percipi*). Our experiences and sensations are produced in us: not by external things (via our sense organs), Berkeley argued, but by God. In short, according to the empiriocriticists, we only experience experiences ("Wir Empfinden unsere Empfindungen", p. 35), while things are merely seen as "complexes of experiences". The world basically is what I experience ("Die Welt ist meine Empfindung", p. 61). The existence of non-thinking substance outside human consciousness is systematically eliminated (p. 17, 51).

According to Lenin, however, dialectical materialism should hold on to the existence of a material world independent of human consciousness. We experience the existence of external reality primarily by interacting with it, in an active, practical manner, via labour, Lenin argues. Human praxis (labour) is our primary source of experience, and this convinces us that the world out there really exists. At the same time, Lenin is clearly aware of the crisis raging in contemporary physics, due to revolutionary discoveries such as X-rays and radioactivity. The material world (e.g. the atom as a basic material entity) seems to evaporate, to dissolve into radiation. Thus, whilst being aware of the challenge to update dialectical materialism, Lenin nonetheless argues that *materialism* should remain the starting point.

A dialectical unfolding can be discerned in this debate, in which the first moment (M_1) is represented by pre-modern metaphysics (say, Aristotle and his medieval followers: Scholasticism), where the soul is considered to be the form of the body. For Aristotle, a concrete living entity is the realisation of an idea. This mode of thinking was negated during modernity, however. The modern metaphysical position was inaugurated by Descartes who developed a dualistic view – dividing the world into the ego (human consciousness) as a "thinking thing" (*res cogitans*) surrounded by extended things (*res extensa*), thus introducing a compartmentalisation between mind and body, as well as between mind and matter (although Spinoza would subsequently argue that the world is one substance, a thinking and extended whole, with two attributes known to us, namely thought and extension, mind and body). This second moment (M_2) was pushed towards its extreme by Berkeley's solipsism, who dropped the existence of external material reality altogether and solely focussed on his own mind. As Lenin argues, Empiriocriticism can be considered a fin-the-siècle update of this radical bourgeois stance. By claiming that we only have access to the world of sense data, the existence of a material world independent of and predating human consciousness is *negated* and discarded as a metaphysical illusion. We are not entitled to posit the existence of things outside (independent of) human experience. M_2 entails the *negation* of the material dimension of the world.

The challenge, dialectically speaking, is to reach a higher level of comprehension via a *negation of the negation* (M_3), i.e. a position which *negates* and *sublates* both pre-modern metaphysics (M_1) and bourgeois idealism (M_2), thereby *overcoming* both antithetical positions. To do this, we must come to terms with the revolutionary and unsettling insights produced by twentieth-century science. Rather than relapsing into pre-modern metaphysical conceptions, dialectical materialism aims to develop a science-compatible version of materialism. Dialectically speaking it is clear that both opposites or antagonists – both traditional (naive) materialism and idealism – have something in common. They both take the phenomenal world of human experience as their starting point, and the issue at stake is whether or not it is admissible to posit the existence of a material world beyond human consciousness. With the help of powerful mathematics and highly advanced technologies, however, modern science has opened up completely unknown and unimaginable dimensions of the material world, far beyond the confines of human understanding: the extremely small world of molecules, atoms and elementary particles (studied by modern chemistry and quantum physics) and the extremely large world of galaxies evolving in spacetime (studied by astrophysics). It is only by coming to terms with science in both directions (the hyper-small and the hyper-large) that dialectical materialism may develop a "sublated" understanding (a negation of the negation).

To phrase it in contemporary terms: this third position neither opts for traditional materialism (since the material world as we know it from every-day experience, and as it is studied by classical physics, is obliterated and eliminated by quantum physics, molecular life sciences research and astrophysics) nor for idealism or Empiriocriticism (the initial "negation" which is now itself negated by this third position). Contemporary technoscience discloses an unknown world existing beyond the reach of unaided human consciousness and sensitivity, a world which is unimaginable and imperceptible for us, which defies the basic structures of human experience and is only accessible via advanced mathematics and scientific technicity. Lenin's book, one could argue, represents a moment of transition, hovering somewhere between M_2 and M_3. He emphasises (in a polemical manner) the shortcomings of Empiriocriticism, is clearly aware of the need for a third dialectical step, but without really being able to realise this step himself because, unlike later authors such as Haldane and Bernal, he studied this debate in libraries and was not really physically *there* as far as technoscience was concerned.

Dialectically speaking, the second moment represents bourgeois epistemology (M_2). Starting point is the ego, which not only gives rise to an egocentric political philosophy (e.g. an ideology of individual autonomy and social contracts, of original positions and egocentric self-sufficiency, reflected by the Robinson Crusoe theme, etc.), but also to an egocentric epistemology: the idea that the world *is* what *I* experience. While Empiriocriticism is a radical version of this idea, a basic affinity can be discerned with Kantianism and neo-Kantianism as well. Kant had posited the concept of the thing-in-itself (the noumenal dimension of objectivity, beyond the phenomenal realm of human experience) as something which is inaccessible to human understanding (Kant, 1781/1975). Idealism (Empiriocriticism) merely took the final step: if the noumenal thing-in-itself is unreachable, why not get rid of it altogether?

From a dialectical materialism perspective, however, this debate now takes a completely different turn as we are confronted with the results of contemporary technoscience. After the fin-the-siècle scientific revolution (the discovery of the electron, the emergence of quantum physics, of relativity theory, of genetics, of molecular life sciences research, etc.), the noumenal dimension of nature has been effectively revealed with the help of advanced technicity (e.g. contrivances such as elementary particle colliders, radio telescopes, spectroscopy, etc.). Technoscience as a praxis has effectively disclosed the noumenal realm of natural processes and entities (of protons and quarks, of nucleotides and amino acids, etc.). It has opened up the basic molecular structure of life and matter. Our understanding of materiality has been radically transformed and sublated, so that our conception of materiality as such (from Higgs-bosons up to stellar formations) has been uplifted, reaching a higher plane of complexity and comprehension (M_3), and the same applies to our bio-molecular understanding of living systems. In short, although our understanding of matter has dramatically changed since the days of Friedrich Engels, the existence of an external world as such (the core issue of bourgeois metaphysics) is no longer our major concern. It is marginalised into a purely academic quandary, because the noumenal structure of reality has effectively been made intelligible by technoscience as an interactive research praxis, continuously interacting with matter and nature in an experimental manner (high-tech scientific experimentalism as a particular mode of human praxis). Building on Engels, a dialectical materialism perspective would emphasise the role of scientific experimental *labour* in this endeavour, which put an end to futile bourgeois speculations (bourgeois mind games).

Dialectically speaking, although scholars like Lukács claimed to endorse a dialectical view on human society, they reverted to a bourgeois perspective as far as the realm of science and nature was concerned. These scholars worked in libraries rather than laboratories, quite remote from the actual world of scientific research (Sheehan, 1985/2017). Taking Engels as their key source of inspiration, a genuine dialectical materialist perspective on contemporary science was developed by dialectical scientists such as Haldane, Bernal and Needham in the 1930s, in whose writings the tensions between the *library* and the *laboratory* perspective on science and nature were sublated and integrated into a comprehensive, genuinely dialectical view.

In Marxist discourse, however, this endeavour (the development of a dialectics or dialectical materialist view of nature) remained a contested undertaking. Lukács (1923/1971) was probably the first but certainly not the last Marxist scholar who viewed the application of dialectics to nature as problematic (Kangal, 2019, p. 218), arguing that dialectics should be limited to the realms of history and society, as the dynamics of contradiction and antagonism should allegedly be seen as a social, not a natural phenomenon.

Dialectically speaking, however, this is an untenable position, first of all because dialectics urges to move beyond such "bourgeois" oppositions (nature versus society, natural science versus social science, etc.). Moreover, the view of nature opened up by the natural sciences in the twentieth century reveals a remarkably dialectical series of processes, abounding in dialectical antagonisms and contradictions. Novelty emerges in nature because of the internal contradictions and crises of previous states (Bernal, 1937). Organic life (as "negative entropy") is something inherently dialectical, consisting of constantly emerging and resolving biotic processes (Engels, 1878/1962, p. 112). Take for instance the theory of evolution (one of the three key discoveries of the nineteenth century, according to Engels as we have seen) where the debate concerning the question whether nature evolves in a gradual (Darwinian) fashion or in a leap-like fashion (via catastrophes, disruptive transitions, etc.) has been overcome (sublated) by the punctuated equilibrium theory developed by dialectical biologists Stephen Jay Gould and Niles Eldredge (Eldredge & Gould, 1972; Rose, 1997; Gould, 2002, p. 745 ff.; Clark & York, 2005), reconciliating both moments on a higher level of comprehension, arguing that nature (comparable to human society and history) evolves *both* incrementally *and* through radical transitions. Or, to stay closer to the work of Engels, take the development of a natural organism, say a plant. The seed containing the program of life ("heredity", DNA) is exposed to a hazardous, entropic environment which threatens to negate and obliterate this fragile life form, unless the plant manages to *use* its environment as a resource for growth and protection (the *negation of the negation*), so that two antagonistic forces (nature and nurture, genome and environment) eventually complement each other. As was already indicated above, living entities basically *are* this dialectical interaction. The technicity of modern science takes us far beyond the type of experiences provided by our natural sense organs (as products of evolution).

Rather, it opens up the noumenal, molecular "essence" of living systems. But to really and convincingly address this issue, we have to shift our focus towards a concrete dialectical assessment of an actual research practice; which is precisely what the final section of this chapter purports to do.

From Artificial Proteins to Synthetic Cells

Life, according to Engels, is the mode of existence of proteins (*Eiweißkörper*),[25] characterised by the constant self-renewal of the chemical constituents of these proteins, a conception which echoes Hegel's view of life as a self-renewing chemical process made perennial, discussed above. Egg-white (*Eiweiß*) is a term which Engels uses here in its modern chemical-industrial sense, as a general denominator for the larger family of protein substances (1878/1962, p. 76).[26] Wherever we find life, we find proteins and vice versa. Proteins represent *noumenal life* or life "*an sich*", they are the essence of "naked life" (p. 76). The lowest living beings known to us are aggregates of proteins and they already exhibit all the essential phenomena of life: they absorb and appropriate substances from their environment and assimilate them, while other substances disintegrate and are excreted: a process known as metabolism. Non-living bodies also change or become involved in chemical combinations (e.g. metals which oxidise and rust), but they thereby cease to be what they were. In living entities, this constant interaction with the environment (a cause of entropic destruction in non-living bodies) is transformed into a fundamental condition of existence (Engels, 1878/1962, p. 76). As soon as metabolism seizes, they decompose and die. Paradoxically therefore, life is in a constant state of flux, being every moment both itself and something else, as a result of processes which are self-implemented and inherent to life. Hence it follows that, if chemistry ever succeeds in producing proteins artificially from chemical components (Engels, 1878/1962, p. 67, 76), these substances must display phenomena of life (metabolism, growth,

[25] "Leben ist die Daseinsweise der Eiweißkörper" (1878/1962, p. 75). The term *Eiweiß* may be translated either in a general sense (as *protein*), or in a more specific sense, as *albumin*: the type of proteins egg white contains.

[26] "Eiweißkörper im Sinn der modernen Chemie, die unter diesem Namen alle dem gewöhnlichen Eiweiß analog zusammengesetzten Körper, sonst auch Proteinsubstanzen genannt), zusammenfast" (Engels, 1878/1962, p. 76). Proteins are macromolecules consisting of extended chains of amino acids and performing a vast array of functions within organisms. They were first described by the Dutch chemist Gerardus Johannes Mulder in 1838 (Harold, 1951), who discovered that these substances had the same empirical formula ($C_{400}H_{620}N_{100}O_{120}P_1S_1$) (Perrett, 2007). Prior to "protein", which is derived from ancient Greek and means primary (primary substance), other names were used such as "albumins" or "albuminous substances" (*Eiweißkörper*), derived from "albumin" (egg white).

etc.),[27] however weak these may be, provided scientist find out what the right nutrition for such a substance would be.

Engels perceives life from a dialectical position. Initially, we know life from every-day experience and contemplate about it (M_1), but at a certain point, a more active and experimental approach is adopted, so that living entities are taken apart, dismantled and analysed. This analysis (*Zerlegung*) entails an element of violence, resulting in the *obliteration* of living entities, a process which reveals the *negativity* of experimental science (M_2). In order to understand life, scientists systematically destroy (negate) it in their laboratories, in order to find out that living substances, which we know from every-day experience, actually consist of molecular substances called *proteins*, which can be analysed further, so that their chemical composition is revealed. The inevitable third step, dialectically speaking, is the negation of the negation (M_3). Starting from a *general* understanding of life (A), but proceeding on the basis of accumulated knowledge concerning *particular* aspects of life (B), scientists will eventually try to reconstruct living matter (proteins) *in vitro*. The final aim inevitably will be to technologically reproduce proteins: putting the basic components together again to produce something which is a *concrete whole*; – something like an artificial cell, the concrete universal of life (E).

This same line of thinking, developed in *Anti-Dühring*, can also be encountered in *Dialectics of Nature*. In nineteenth-century biology, Engels points out, the discovery of the structure and function of the cell with the help of advanced microscopes revealed that cells indeed constitute the basic realisation of the concept of life. Meanwhile, in chemistry, through complementary processes of analysis and synthesis, scientists not only discovered the basic molecular constituents of living (organic) matter, but were also able to produce organic compounds *in vitro* that hitherto had only been produced in living organism (*in vivo*), starting with urea, thereby bridging the gap (the ontological divide) between inorganic and organic nature, which Kant had considered to be insurmountable (Engels, 1925/1962a, p. 318). And while biochemists are working hard to understand life in their laboratories, palaeontologists disclose immense palaeontological "archives" which one day may help us to understand the origin of life on Earth (p. 322).

As to the subject pole, paleo-anthropologists reveal the crucial role of tool use and labour in the process of anthropogenesis, the coming into being of human societies and the self-formation of humankind (p. 322), starting with the discovery of the transformation of mechanical motion into heat: i.e. the generation of fire by means of friction (Engels, 1925/1962b, p. 106), and eventually arriving at its counterpart: the transformation of heat into movement via steam engines. Humans are self-made, Engels argues, and the most important product of human labour is humanity as such, most notably the human hand (1925/1962b, p. 445), which coevolved with the human brain (p. 232). Technoscientific research itself still exemplifies this formative interaction between the human hand (active experimental

[27] "Und daraus folgt, dass, wenn es der Chemie jemals gelingen wird, Eiweiß künstliche herzustellen, dies Eiweiß Lebenserscheinungen zeigen muss" (1878/1962, p. 76).

manipulation), the human brain (the organ of thinking) and the natural environment, in order to produce viable knowledge concerning the natural world, although modern science has of course moved far beyond Palaeolithic conditions by developing a conscious *organisation* of the knowledge production process. Whereas Greek thinkers conceived of nature as a whole, modern research involves an active processing of nature, applying the laws of dialectics, albeit often in an "unconscious" manner. But conscious dialectics would optimise this process and result in a more comprehensive view, provided Hegelian dialectics is turned upside down ("umstülpen", p. 335), transforming it from an idealistic approach (focussed on concepts) into a materialist approach (focussed on how these concepts materialise in concrete research practices, in concrete interactions with life and matter).

In the nineteenth century, science resulted in three decisive discoveries as we have seen: the discovery of the cell, the laws of thermodynamics and evolution (p. 468). One big challenge is still awaiting us, Engels argues: explaining the origin of life out of inorganic nature, but modern chemistry is bound to reach this goal (p. 469).[28] Since the artificial production of urea by Wöhler in 1828, there are in principle no obstacles to progress further towards the production of more complex substances in the laboratory, including proteins (albumen). Once the molecular composition of proteins is known, moreover, scientists will try their hands at producing living protein,[29] so that the chemical process will give way to the process of life and the gap (allegedly insurmountable) between inorganic and organic nature will be bridged (1925/1962a, p. 318, 319). This will affect the subject pole as well, for as soon as chemistry is able to produce proteins, it will become a qualitatively different type of science, namely the science of artificial life (p. 522).

Dialectically speaking, this again represents an unfolding triadic development, from the initial discovery of living cells (M_1), via their chemical analysis (M_2) towards re-synthesis (convergence, *Zurückführung*: M_3). One day, scientists will be able to create life artificially (p. 559), by producing proteins and mimicking metabolic processes. As a result, the basic processes of life will become modifiable in a test-tube. This line of thinking builds on what was already brought forward by "old Hegel" himself, namely that, as soon as the chemical process becomes self-sustainable (becomes metabolism), it becomes life.[30] So-called artificial cells

[28] "Nur eines bleibt noch zu tun: die Entstehung des Lebens aus der unorganischen Natur zu erklären. Das heißt auf der heutigen Stufe der Wissenschaft nichts anderes als: Eiweißkörper aus unorganischen Stoffe herzustellen. Diese Aufgabe rückt die Chemie immer näher" (p. 468/469).

[29] "Sobald die Zusammensetzung der Eiweißkörper einmal bekannt ist, wird [die Chemie] an die Herstellung von lebendigem Eiweiß gehen können" (p. 469); "Gelingt es der Chemie, dies Eiweiß in der Bestimmtheit darzustellen … greift der chemische Prozess über sich selbst hinaus, d.h. er gelangt in ein umfassenderes Gebiet, das des Organismus" (p. 520).

[30] See for instance Hegel's comments about the chemical process in his *Enzyklopädie der philosophischen Wissenschaften II*: "Der chemische Prozess ist so ein Analogon des Lebens. Könnte er sich durch sich selbst fortsetzen, so wäre er das Leben; daher liegt es nahe, des Leben chemisch zu fassen"(§ 326); „Wenn die Produkte des chemischen Prozesses selbst wieder die Tätigkeit anfingen, so wären sie das Leben. Das Leben ist insofern ein perennierend gemachter chemischer Prozess" (§ 335).

created by Moritz Traube in 1864 did not yet represent genuine metabolism, Engels argues, but it did represent a symptomatic step. Once upon a time, environmental conditions on planet Earth must have been such that the first protein aggregates could arise spontaneously and evolve into primeval primitive organisms. And one day, in modern laboratories, such conditions may again be reproduced *in vitro*.[31]

Thus, Engels can be credited for having predicted the emergence of efforts to create artificial life in vitro as an inevitable step, eventually resulting in the creation of synthetic cells, as an important dialectical endpoint (turning-point) in the history of science. He thereby prepared the ground for a dialectical assessment of contemporary technoscience, exemplified by projects committed to building a synthetic cell and similar endeavours. A number of dialectical authors, notably scientists, already contributed to the extrapolation of dialectical materialism to contemporary science, such as for instance J.B.S. Haldane (1938/2016) who is still famous for his contribution to the primordial, prebiotic soup hypothesis, which states that life arose gradually from inorganic molecular building blocks, e.g. amino acids. Building on Engels, he defined a number of methodological principles for a dialectical understanding of scientific research, such as the primacy of practice over theory (seeing research first and foremost as a *praxis*, a systematic experimental interaction with nature, building on the conviction that knowledge claims should be tested and validated *in practice*). Another principle is that nature should not be considered as a collection of things, but rather as a series of processes. Science is about change and relies on technological contrivances to study these transformative processes with due exactness and precision. Moreover, science itself progresses in a dialectical manner as well, via the negation and obliteration of existing viewpoints. Currently (in the 1930s), Haldane argued, science is bridging the gap between inorganic and organic nature, between chemistry and biology, for instance via the study of viruses: entities which consist of pure nucleic acid (the noumenal essence of life *as such*) contained in a protein capsule. The metabolic processes of life consist of anabolism and catabolism, of building up and breaking down, as opposites which actually must be seen as complementary and as part of the living cell as a concrete, comprehensive whole. And now that the basic constituents of living systems are being explored, the question arises: how to put Humpty Dumpty together again (p. 98)? Increasingly, partial components of living systems will prove replaceable, even in the case of humans, whose organs may one day be replaced by artificial substitutes (a practice currently known as tissue engineering). Genes are beautiful exemplifications of the dialectics (the creative antagonisms) in nature, Haldane argues, containing a program which is constantly trying to adapt to the environment and vice versa, so that the program may optimally function in a thriving living being. Contrary to genetic determinism, dialectics sees organisms not merely as passive objects, but as active subjects or agents of evolution, adapting to and at the same time modifying their environment. Plant roots and rhizomes change the structure and composition of the

[31] This idea, the spontaneous origin of life from inorganic matter (*generatio aequivoca*), is also discussed by Marx and Engels in their correspondence (1983 III, p. 339, 437). J.B.S Haldane and Alexander Oparin later developed this idea into the Oparin-Haldane hypothesis.

soil, and networks of interacting living things (the biosphere) changed the planet on a spectacular scale, altering the atmosphere irreversibly by adding oxygen (cf. Levins & Lewontin, 1985; Royle, 2014). Neither organism nor environment can be understood without reference to the other (Royle, 2014, p. 103). They alternately perform the role of agent (A), other (O) and product (P) in dialectical cycles (as explained in Hegel's analysis of the chemical process, above).[32]

This reflects a dialectical dynamic. Initially, living entities are seen as stable, balanced wholes (M_1) and the phenomena of life are addressed on a general or *universal* level. Aristotle, for instance, is interested in life as such, in the conceptual understanding of life (*das Allgemeine*: A), although in his anatomical research he began to introduce rudimentary differentiations between particular groups of species (e.g. animals with lungs versus animals with gills). Modern scientific analysis focusses on *particular* processes and dimensions, such as, for instance, heredity or the environment (*das Besondere*: B). Here, multiple antagonistic factors and forces are actually at work: productive tensions between heredity and environment, anabolism and catabolism, growth and equilibrium, etc. (M_2). Finally, we will come to understand how these antagonisms converge into concrete living entities such as living cells, functioning and maintaining high levels of complexity as concrete unities (M_3). Thus, the living cell is the *concrete* realisation of the idea of life (*Einzelheit*: E). And to really understand the living cell, one final step has to be made, namely the technical reproduction of a minimal or artificial cell *in vitro*.

This same idea is further developed by Friedrich Engels in his treatise *Ludwig Feuerbach and the End of Classical German Philosophy* (1886/1962). Again, he argues that bourgeois metaphysical convictions, such as the idea of an insurmountable gap between subject and object, between phenomenal experiences and things-in-themselves, between living and non-living entities, between organic and inorganic nature, etc. must be overcome by experimental labour in laboratories and industries: by science as praxis. Indeed: the ultimate validation of the dialectical materialist conception of natural processes can be achieved by actively reproducing biotic organic entities ourselves, in laboratories and factories. That would finally put an end to the Kantian "thing in itself."[33] Biochemical substances remain "things in

[32] For Joseph Needham, a biochemist and historian of science, specialised in science history in China, dialectics applied both to natural and societal processes. Thus, he emphasised the dialectical nature of natural phenomena such as muscle contraction (Chen, 2019). He saw nature as a series of dialectical syntheses. "From ultimate particle to atom, from atom to molecule, from molecule to colloidal aggregate, from aggregate to living cell, from organ to body, from animal body to social association... Nothing but energy (as we now call matter and motion) and the levels of organisation (or the stabilized dialectical syntheses) at different levels have been required for the building of our world" (Needham, 1943, p. 15). Living organisms and their environment are as inextricably interlaced as science is with society and its history. Indeed, as Needham phrases it, Marx and Engels set "Hegelian dialectic within evolving nature" (1983, p. 15; cf. Nappi & Wark, 2019).

[33] "Wenn wir die Richtigkeit unsrer Auffassung eines Naturvorgangs beweisen können, indem wir ihn selbst machen, ihn aus seinen Bedingungen erzeugen, ihn obendrein unseren Zwecken dienstbar werden lassen, so ist es mit dem Kantschen unfassbaren "Ding an sich" zu Ende. Die im pflan-

themselves" only until biochemistry can artificially produce them, one after the other, because then these processes and substances become things *for us*.[34]

Dialectics also helps us to come to terms with the enigma of the origin of life. Under current terrestrial circumstances, life can no longer emerge spontaneously (*generatio aequivoca* seems no longer possible) because life emerged as a third moment in a dialectical unfolding. Initially, primeval organisms (aggregates of living albumin as Engels phrased it: M_1) emerged, able to withstand their entropic, abiotic, anaerobic environment (M_2) which threatened them with destruction. These budding life forms became increasingly able not only to survive, but also to thrive and to use their primeval environment (now known as the primordial soup) as a resource for development and growth (M_3). In the present situation, biotic, aerobic environments effectively block such a trajectory. Indeed, as Levins and Lewontin phrased it, the primary requirement for the origin of life is now the absence of life (1985, p. 46). Under current circumstances, fragile neo-life requires a gnotobiotic, fully controlled environment, which can only be provided by the purified ambiances of technoscientific laboratories (Zwart, 2019a). Thus, the synthetic cell emerges as the concrete realisation of the *technoscientific* concept of life, and as the reconciliation of self-conscious reason (i.e. technoscience) with the reason (logos) inherent in existing nature.[35]

But precisely this may also prove a weakness. Should the experiment succeed, the initial experience of success will probably be short-lived: a fate which befalls most if not all the triumphs of scientific inquiry. Before long, discontent will set in, in the form of the *experience* that, apparently, we have missed something and that these artificial ("fake") cells fail to fully grasp and reproduce the astounding complexities of living systems, so that the synthetic cell will only prove a temporary station on the long and winding pathway of the dialectical unfolding of scientific consciousness. This *particular* triumph will be negated, but rather than clinging to this *particular* trial (and the – apparently constricted – understanding of life on which it built), technoscience will doubtlessly desire to progress farther. As a positive result, the inevitable experience of *Enttäuschung* will inform and enable the development of even more advanced programs and efforts to realise a negation of this negation in the future.

Ultimately, the dialectical objective (the envisioned *end result*) remains the will to *supersede* the disruptive divergence between technology and nature, thereby making biotechnology sustainable and bio-compatible again. In the course of the industrial revolution, bourgeois technoscience developed into a detrimental

---

zlichen und tierischen Körper erzeugten chemischen Stoffe blieben solche "Dinge an sich", bis die organische Chemie sie einen nach dem andern darzustellen anfing; damit wurde das "Ding an sich" ein Ding für uns" (Engels, 1886/1962, p. 276).

[34] Cf. Bernal (1937): scientists of today are learning to manipulate life very much as their predecessors learned to manipulate chemical substances, so that life ceases to be a mystery and is becoming a utility.

[35] Cf. Hegel, "den höchsten Endzweck der Wissenschaft [ist] die Versöhnung der selbstbewussten Vernunft mit der seienden Vernunft, mit der Wirklichkeit hervorzubringen" (1830/1986, § 6, p. 47).

technological power of epochal impact, critically affecting the metabolism between human society and the natural environment. Already in early publications, Engels acutely described how in booming cities such as Manchester (1845/1962, p. 237, 250, 254), techno-industrial disruption resulted in miasmic air, hideous smells (p. 259) and polluted puddles (p. 274), such as the river Irk, which had become a narrow, coal-black, foul-smelling stream, filled with refuse and excrements (p. 282, 295), creating optimal conditions for the spread of infectious diseases such as cholera (Zwart, 2019b). While Engels saw cities themselves as complex processes, rather than as entities (Royle, 2014, p. 100), ecological disruption was a decidedly *global* process, and in *Dialectics of Nature* Engels describes, for instance, how Spanish planters in Cuba, by burning down forests in order to plant their profitable coffee trees, caused tropical rainfall to wash away the now unprotected upper stratum of the soil (1925/1962a, p. 455). While during the artisanal agricultural era (M_1) the metabolism between humanity and nature had remained relatively sustainable, the industrial revolution gave rise to an "ecological rift" (Foster, 2000; Foster et al., 2010): to massive processes of disruption (environmental pollution, soil degradation, urbanisation, alienation) which catastrophically aggravated during the current era of globalisation (M_2). These developments fuelled a revival of Marxist approaches to the current ecological crisis (Foster, 2000; Moore, 2016; Royle, 2019), underscoring the detrimental environmental and biological impact of egocentric bourgeois metaphysics on our global economic and ecological system. Now that global disruption (climate change, mass extinction, ecological destruction) is being pushed to its extreme, the challenge is more than ever to supersede the "*Entzweiung*" between technology and nature, between urban and rural, etc., on a higher level of sophistication (M_3).

References

Aldersey-Williams, H. (2020). *Dutch light: Christiaan Huygens and the making of science in Europe*. Picador.

Arthur, C. (2004). Marx's *Capital* and Hegel's *Logic*. In *The new dialectic and Marx's Capital* (pp. 79–111). Brill.

Benfey, T., & Travis, A. (1992). Carl Schorlemmer: The red chemist. *Chemistry and Industry,* 441–444.

Bernal, J. D. (1936). *Engels and science*. Labour monthly pamphlets 6. Trinity Trust.

Bernal, J. D. (1937). Dialectical materialism and modern science. *Science and Society, 2*(1), 58–66.

Bernard, C. (1966). *Introduction à l'étude de la médicine expérimentale*. Garnier-Flammarion.

Blackledge, P. (2017). Practical materialism: Engels's anti-Dühring as Marxist philosophy. *Critique, 45*(4), 483–499. https://doi.org/10.1080/03017605.2017.1377927

Burman, A. (2018). Back to Hegel!: Georg Lukás, dialectics, and Hegelian Marxism. In A. Burman & A. Baronek (Eds.), *Hegelian Marxism: The uses of Hegel's philosophy in Marxist theory from Georg Lukács to Slavoj Žižek* (pp. 17–34). Södertörns Högskola.

Caudwell, C. (1939/2017). *The crisis in physics*. Verso.

Chen, B. (2019). Needham, matter, form and us. *Isis, 110*(1), 122–128.

Clark, B., & York, R. (2005). Dialectical materialism and nature. An alternative to economism and deep ecology. *Organization & Environment, 18*(3), 318–337. https://doi.org/10.1177/1086026605279387

Dietzgen, J. (1869/1961). Das Wesen der menschlichen Kopfarbeit. In *Ausgewählte Werke I* (pp. 15–139). Akademie Verlag.

Duran-Novoa, R., Leon-Rovira, N., Aguayo-Tellez, H., & Said, D. (2011). Inventive problem solving based on dialectical negation, using evolutionary algorithms and TRIZ heuristics. *Computers in Industry, 62*, 437–445.

Eldredge, N., & Gould, S. J. (1972). Punctuated equilibria: An alternative to phyletic gradualism. In T. Schopf (Ed.), *Models in Paleobiology* (pp. 82–115). Freeman Cooper.

Engels, F. (1845/1962). *Die Lage der arbeitenden Klasse in England, nach eigener Anschauung und authentischen Quellen.* In Karl Marx – Friedrich Engels – Werke Band 2 (pp. 225–506). Dietz Verlag.

Engels, F. (1878/1962). Herrn Eugen Dührings Umwälzung der Wissenschaft (Anti-Dühring). *Marx Engels Werke XX* (pp. 1–303). Dietz Verlag.

Engels, F. 1880/1962. *Die Entwicklung des Sozialismus von der Utopie zur Wissenschaft*. In *Marx Engels Werke XIX* (pp.177–228). Dietz Verlag.

Engels, F. (1886/1962). *Ludwig Feuerbach und der Ausgang der klassischen deutschen Philosophie. Marx Engels Werke XXI*. Dietz Verlag.

Engels, F. (1893/1977). Vorwort. Das Kapital: Kritik der Politischen Ökonomie, Zweiter Band. Karl Marx – Friedrich Engels – Werke Band 24, pp. 7–27.

Engels, F. (1925/1962a). *Dialektik der Natur*. In *Marx Engels Werke XX*, pp. 305–570.

Engels, F. (1925/1962b). Anteil der Arbeit an der Menschwerdung des Affen. In: F. Engels (1925/1962) *Dialektik der Natur*. Marx Engels Werke 20 (pp. 444–455). Dietz Verlag.

Feenberg, A. (2017). Why students of the Frankfurt School will have to read Lukács. In M. J. Thompson (Ed.), *The Palgrave handbook of critical theory*. https://doi.org/10.1057/978-1-137-55801-5_6

Ferrini, C. (2011). The transition to organics: Hegel's idea of life. In: S. Houlgate, M. Bauer (eds.), *A companion to Hegel* (pp. 203–224). Oxford: Blackwell.

Foster, J. B. (2000). *Marx's ecology: Materialism and nature*. Monthly Review Press.

Foster, J. B., Clark, B., & York, R. (2010). *The ecological rift: Capitalism's war on the earth*. Monthly Review Press.

Gould, S. J. (2002). *The structure of evolutionary theory*. Belknap.

Griese, A., & Pawelzig, G. (1986). *Einführung in Engels' Schrift Dialektik der Natur*. Dietz Verlag.

Griese, A., & Pawelzig, G. (1995). Why did Marx and Engels concern themselves with natural science? *Nature, Society, and Thought, 8*(2), 125–138.

Haldane, J. B. S. (1938/2016). *The Marxist philosophy and the sciences*. New York: Routledge.

Hamza, A. (2016). Going to one's ground: ŽiŽek's dialectical materialism. In A. Hamza & F. Ruda (Eds.), *Slavoj Žižek and dialectical materialism* (pp. 163–175). Palgrave MacMillan.

Harold, H. (1951). Origin of the word "protein". *Nature, 168*(4267), 244. https://doi.org/10.1038/168244a0

Hegel, G. W. F. (1807/1986). *Phänomenologie des Geistes. Werke III*. Suhrkamp.

Hegel, G. W. F. (1830/1986). *Enzyklopädie der philosophischen Wissenschaften II. Werke IX*. Suhrkamp.

Hegel, G. W. F. (1831/1986). *Wissenschaft der Logik II. Werke VI*. Suhrkamp.

Hundt, M. (2014). Wie und zu welchem Ende studierte Marx Geologie? *Sitzungsberichte der Leibniz Sozietät der Wissenschaften zu Berlin, 121*, 117–133.

Hunt, T. (2009). *The frock-coated communist: The life and times of the original champagne socialist*. Penguin.

Kangal, K. (2019). Engels' intentions in *dialectics of nature*. *Science & Society, 83*(2), 215–243.

Kant, I. (1781/1975). *Kritik der reinen Vernunft. Werke 3*. Wissenschaftliche Buchgesellschaft.

Kennedy, H. (1977). Karl Marx and the foundations of differential calculus. *Historia Mathematica, 4*(3), 303–318. https://doi.org/10.1016/0315-0860(77)90058-1

Lefèvre, W. (2005). Science as labour. *Perspectives on Science, 13*(2), 194–225.

Lenin, V. I. (1908/1979). *Materialismus und Empiriokritizismus: kritische Bemerkungen über eine reaktionäre Philosophie. Werke 14*. Dietz Verlag.
Levine, N. (1957). *The tragic deception: Marx contra Engels*. Clio Press.
Levins, R., & Lewontin, R. (1985). *The dialectical biologist*. Harvard University Press.
Lukács, G. (1923/1971). *History and class consciousness: Studies in Marxist dialectics*. MIT Press.
Lukács, G. (1978). *The ontology of social being 2: Marx*. Merlin Press.
Lukács, G. (1980). *The ontology of social being 3: Labour*. Merlin Press.
Marx, K. (1857/1961). *Einleitung* zur Kritik der politischen Ökonomie. Karl Marx – Friedrich Engels – Werke Band 13, pp. 615–644;
Marx, K. (1859/1961). *Vorwort* zur Kritik der politischen Ökonomie. Karl Marx – Friedrich Engels – Werke Band 13, pp. 7–14.
Marx, K. (1939/1983). Einleitung. Grundrisse. Karl Marx – Friedrich Engels – Werke Band 42, pp. 19–45.
Marx, K. (1867/1979a). Vorwort. Das Kapital: Kritik der Politischen Ökonomie, Erster Band. Karl Marx – Friedrich Engels – Werke Band 23, pp. 11–17.
Marx, K. (1867/1979b). Nachwort zur zweiten Auflage. Das Kapital. Karl Marx – Friedrich Engels – Werke Band 23, pp. 18–28.
Marx, K., & Engels, F. (1983). *Der Briefwechsel*. Deutscher Taschenbuch Verlag.
Moore, J. (2016). *Anthropocene or capitalocene? Nature, history, and the crisis of capitalism*. PM Press.
Nappi, C., & Wark, M. (2019). Reading Needham now. *Isis, 110*(1), 100–108.
Needham, J. (1943). *Time, the refreshing river*. Allen & Unwin.
Pannekoek, A. (1901). De filosofie van Kant en het Marxisme. *De Nieuwe Tijd* 6: 549–564, 605–620, 669–688.
Pannekoek, A. (1951/1961). *A history of astronomy*. Allen & Unwin.
Pannekoek, A. (1982). *Herinneringen: Herinneringen uit de arbeidersbeweging/Sterrenkundige herinneringen*. Van Gennep.
Perrett, D. (2007). From "protein" to the beginnings of clinical proteomics. *Proteomics: Clinical Applications, 1*(8), 720–738. https://doi.org/10.1002/prca.200700525
Rees, J. (1994). Engels's Marxism. *International Socialism 2*, 65/ETOL.
Rose, S. (1997). *Lifelines: Life beyond the gene*. Vintage.
Royle, C. (2014). Dialectics, nature and the dialectics of nature. *International Socialism 141*.
Royle, C. (2019). Marxism and the anthropocene. In M. Empson (Ed.), *System change not climate change: A revolutionary response to environmental crisis*. Bookmarks.
Sartre, J.-P. (1960/2004). *Critique of dialectical reason 1: Theory of practical ensembles*. Verso.
Sartre, J.-P., Garaudy, R., Hyppolite, J., Vigier, J.-P., & Orcel, J. (1962). *Marxisme et existentialisme: Controverse Sur la dialectique*. Plon.
Schorlemmer, C. (1879). *The rise and development of organic chemistry*. Cornish/Simpkin & Marshall.
Schrödinger, E. (1944/1967). *What is life? The physical aspect of the living cell*. Cambridge University Press.
Schweiger, G. (2011). Naturphilosophie bei Friedrich Engels: Eine Interpretation der Dialektik der Natur. In E. Hamberger, O. Neumaier, B. Ritterbusch-Nauwerck, & E. D. Roscher (Eds.), *Natürlich Kunst …* (pp. 127–146). LIT-Verlag.
Sheehan, H. (1985/2017). *Marxism and the philosophy of science: A critical history (the first hundred years)*. Verso.
Sim, S. (Ed.). (2000). *Contemporary continental philosophy: The new scepticism*. Routledge.
Stanley, J. (1989). The Marxism of Marx's doctoral dissertation. *Journal of the History of Philosophy, 33*(1), 133–158.
Stanley, J. (1991). Marx, Engels and the administration of nature. *History of Political Thought, 12*(4), 647–670.

Tai, C. (2017). Left radicalism and the Milky Way: Connecting the scientific and socialist virtues of Anton Pannekoek. *Historical Studies in the Natural Sciences*, *47*(2), 200–254. arXiv:1705.06107. https://doi.org/10.1525/hsns.2017.47.2.200.
Tai, C., Van der Steen, B., & Van Dongen, J. (2019). *Anton Pannekoek: Ways of viewing science and society*. Amsterdam University Press.
Thomas, P. (2008). *Marxism and scientific socialism: From Engels to Althusser*. Routledge.
Vincent, J. (2016). The trade-off: A central concept for biomimetics. *Bioinspired, Biomimetic and Nanobiomaterials, 6*(2), 67–76. https://doi.org/10.1680/jbibn.16.00005
Zilsel, E. (2003). *The social origins of modern science* (Boston studies in the philosophy of science) (Vol. 200). Kluwer.
Žižek, S. (2012/2013). *Less than nothing: Hegel and the shadow of dialectical materialism*. Verso.
Žižek, S. (2014/2015). *Absolute recoil: Towards a new foundation of dialectical materialism*. Verso.
Žižek, S. (2016/2019). *Disparities*. London: Bloomsbury.
Zwart, H. (2000). A short history of food ethics. *Journal of Agricultural and Environmental Ethics, 12*, 113–126.
Zwart, H. (2009). Biotechnology and naturalness in the genomics era: Plotting a timetable for the biotechnology debate. *Journal of Agricultural and Environmental Ethics, 22*, 505–529.
Zwart, H. (2013). The genome as the biological unconscious – And the unconscious as the psychic 'genome'. A psychoanalytical rereading of molecular genetics. *Cosmos and History: Journal of Natural and Social Philosophy, 9*(2), 198–222.
Zwart, H. (2017). The oblique perspective: Philosophical diagnostics of contemporary life sciences research. *Life Sciences, Society & Policy, 13*, 4. https://doi.org/10.1186/s40504-017-0047-9
Zwart, H. (2019a). From primal scenes to synthetic cells. *eLife, 8*, e46518. https://doi.org/10.7554/eLife.46518
Zwart, H. (2019b). Fabricated truths and the pathos of proximity: What would be a Nietzschean philosophy of contemporary technoscience? *Foundations of Science*. https://doi.org/10.1007/s10699-019-09599-3

Chapter 4
Psychoanalysing Technoscience

While the previous chapter discussed the shift from Hegelian dialectics to dialectical materialism, this chapter addresses the shift from dialectics to psychoanalysis, notably in France, paying due attention to the productive tensions between both approaches. After a concise exposition of Freudian psychoanalysis, focussing on *Beyond the Pleasure Principle*, the text in which Freud explicitly "plunged into the thickets" of modern biology (Gay, 1988, p. 401), I will extensively discuss the views of Gaston Bachelard and Jacques Lacan on technoscience. Building on a previous publication (Zwart, 2019a), where I already presented a psychoanalytic understanding of technoscience, which I don't want to duplicate here (focussing on the oeuvres of Sigmund Freud, Carl Gustav Jung, Gaston Bachelard and Jacques Lacan), I will now emphasise the continuity between dialectics and psychoanalysis, indicating how dialectics remains an important moment in Bachelard's and Lacan's efforts to develop a psychoanalysis of technoscience, both as a discourse and as a practice. In addition, I will elucidate the added value of this convergence by extrapolating it to three concrete case studies, one borrowed from particle physics and two from life sciences research: the Majorana particle, the malaria mosquito and the nude mouse.

Psychoanalysis and the Psychic Machine

According to Sigmund Freud (1920/1940), to come to terms with processes of knowledge production, we should not start from the idea of a pre-established harmony between subject (psyche) and object (external reality). Rather, our point of departure should be the chronic disparity between both poles. The initial encounter with the threatening real is a traumatic experience, exemplified by the trauma of birth. As Slavoj Žižek (2016/2019, p. 157) points out, Kant already interpreted the screams ("Geschrei") produced by a child at birth as a symptom of indignation in response to the experience that human autonomy is significantly hampered by bodily constraints. For psychoanalysis, the birth trauma emphasises the

H. Zwart, *Continental Philosophy of Technoscience*, Philosophy of Engineering and Technology 38, https://doi.org/10.1007/978-3-030-84570-4_4

maladaptation of the human organism to its natural (primal) environment. An important objective, of organisms in general, but of the human organism in particular, is immunisation against the real.[1] Contrary to most other mammals, human beings enter prematurely into their world, marked by negation and lack: the *absence* of fur and claws, the *inability* to move and walk, so that, with the help of technology, additional immunisation devices (a cradle, a baby carrier, a home, etc.) must be installed to compensate for this lack (negating the negation). Rather than being "open" to externality and otherness, averting, neutralising, and incorporating external input becomes a key existential challenge.

These views are already proposed by Freud during the early years of psychoanalysis, in his letters to Wilhelm Fliess and in an unpublished manuscript known as the *Entwurf.* In these documents, Freud describes the human psyche as a "machine" (Freud, 1950, p. 139), an "apparatus" (p. 270) consisting of various "systems", wherein energy quanta circulate, designed to attenuate excessive stimulation and excitation. Indeed: "I am a machine" (p. 271; cf. Zwart, 1995). The main function of this machine (the neural apparatus) is to act as a screen (a "Quantitätsschirm") to contain the influx of potentially disruptive energy quantities, entering the system from outside (p. 390). The psychic apparatus acts as a filter which allows only small quotients of external energy quantities to affect the psychic system (p. 394). Thus, the main task is to protect the system from intrusion of disruptively large quantities. At first glance, the role of the "reality principle" seems to be to enhance the ego's ability to defer immediate gratification (pleasure). Yet, on closer inspection, the role of the reality principle first and foremost is to *shield* the ego, by forfending traumatic *confrontations* with raw reality. The primary role of the reality principle is not to *expose* the subject to the inexorable real, but rather to allow *carefully selected bits of reality* into the system, so that these "raw quantities" can be processed and transformed, and reality becomes livable for the ego. In short, whereas traditional philosophy emphasises world-openness and intentionality as starting point for human understanding, psychoanalysis rather emphasises the epistemic role of resistance as a mechanism of defence (Zwart, 2019a).

This line of thinking is taken up by Freud many years later, in *Beyond the Pleasure Principle* (Freud, 1920/1940). The pivotal role of resistance, Freud argues, is underscored by human anatomy. We are covered by protective skin (which again is covered with an extra protective layer known as clothes), while our sense organs are miniature apertures whose primary purpose is to provide protection against overstimulation (*Reizschutz*). Rather than being open to the world, our bodies protect and immunise us from the threatening Real. This tendency of living organisms to insulate themselves from the outside world already applies to microorganisms, coaxed inside their cell membranes. Our vulnerable bodies protect

[1] Dialectically speaking, the syllogism takes us from tranquillity *in utero* (M_1) via the trauma of birth (M_2), counteracted by parental support and immunisation, up to relative independence ("autonomy") as an *outcome* (M_3). The prematurity of humans *radicalises* the moment of negativity (M_2), so that culture and technology are needed to bridge the gap towards attaining the negation of the negation ($M_2 \rightarrow M_3$).

themselves against overstimulation, but this applies to the human psyche as well. Protection against external stimuli is a life task at least as important as sensitivity and receptivity (Freud, 1920/1940, p. 27). Our sense organs are like little antennae that select small samples of exteriority, allowing us to assess minute quantities of input. Our primary objective is to safeguard our psychic integrity from intrusive traumas.

Freud elucidates the topology of the human psyche by comparing it with the anatomy of the human eye. Darkness is the default, and the eye is basically a camera obscura, while pupil and cornea allow only small samples of diffracted light to enter the eye and reach the retina (cf. § 2.4). Raw light is filtered and processed. We may also compare the psyche to a laboratory, again a space where everything (light, air, temperature, etc.) is meticulously conditioned and controlled: safeguarded from external disturbances, so that only carefully selected samples of reality are subjected to analysis, with the help of contrivances and agents, as Marx also argued (1867/1979; p. 12). Gradually, the scope of our vision is broadened with the help of artificial extensions, artificial sense organs and electronic gadgets, so that humans gradually evolve into "prosthetic superhumans" (Freud, 1930/1948). Thus, after immunisation and selection, the next challenge is overcompensation. In the global environment of today, humans are exposed to technologically mediated overstimulation (information overload). While laboratories may be considered as materialisations of Freud's concept of the psyche (operating as an immunisation device), the currently emerging global networks of laboratories are confronting us with informational overabundance (data litter). Knowledge scarcity has given way to Gargantuan data collections. Let this suffice as a starting point for outlining a psychoanalytic approach to understanding technoscience. I will now zoom in on the work of two authors who made major contributions to the further development of this approach.

Gaston Bachelard: The Inherent Dialectics of Technoscience

Gaston Bachelard's philosophy of science is a *psychoanalysis of technoscience*, focussing on the epistemological rupture between pre-scientific and technoscientific ways of being-in-the-world, and on the crucial role of surveillance in technoscientific research (Zwart, 2019a, 2020a). Bachelard thematises the rupture between "pre-scientific" and "scientific" as a rupture between imaginative and symbolic styles of thinking, arguing that science is iconoclastic, negating the archetypal images and worldviews that dominate pre-scientific contemplation, and replacing them with the (mathematical, physical and chemical) symbols, equations and neologisms of exact or calculative thinking. In erudite historical analyses he elaborates a theme that was already addressed by Hegel (cf. § 2.12), namely the diremption of ancient elements (earth, water, air, fire) into elementary chemical components (chemical elements). For modern chemistry, Bachelard (1938/1949) argues, while water is being redefined as H_2O, fire as a life-world phenomenon (associated with images of hearths, fireplaces, campfires, torches, etc.) is no longer a valid concept.

It is replaced by validated scientific concepts such as "energy" and "combustion" which can be captured in equations.

Subsequently, Bachelard demonstrates how, for those who have managed to adopt and internalise the logic of science, methodological norms function as a *super-ego*, critically monitoring technoscientific research practices, urging researchers to recognise and overcome their epistemological deficiencies and obstacles. Technoscience is presented by Bachelard as a formative and transformative praxis, drastically affecting the external environment while at the same time converting the individuals involved into reliable subjects: egos of technoscience. While the *objects* of science are laboratory artefacts (rather than natural entities), the *subjects* of science, i.e. the researchers themselves, are reformed and remoulded as well,[2] via systematic scientific training, a formative process which amounts to a spiritual "reformation" (Bachelard, 1938/1970, p. 23). In short, Bachelard describes the subject-object interaction as a dialectical dialogue which transforms and affects both poles.

According to Bachelard, a dialectical unfolding can be discerned in technoscience. Initially, human beings are imprisoned in traditional worldviews, under the sway of archetypal images (the first moment, M_1). These worldviews are relentlessly challenged and negated, however, by the disruptive insights produced by technoscience (the second moment, M_2). Indeed, according to Bachelard, technoscience is decidedly *iconoclastic*, and in a significant part of his oeuvre, Bachelard emphatically takes sides with the iconoclastic, negating tendencies of technoscience (Zwart, 2019a, 2020a). Eventually, however, Bachelard opts for a more comprehensive approach, seeing technoscientific negation and poetic imagination as complementary dimensions of human experience. Dialectically speaking, this is the negation of the negation (the third moment, M_3). The negative attitude towards archetypal images is sublated and overcome, to that technoscience and imagination become reconciled again. And indeed, technoscience is a prolific producer of powerful images (the Big Bang, the Rutherford-Bohr model of the atom, the Double Helix, etc.).

Bachelard's psychoanalysis of technoscience entails a dialectical "phenomenology" (in the Hegelian sense) of technoscientific research practices as they emerge on the scene in the course of history. During the first (pre-scientific) stage, poetic intuitions are triggered by observations via natural sense organs (M_1), a stage of thinking which is under the sway of archetypal ideas, functioning in an uncritical and spontaneous manner and resulting in poetic, animistic and mythological worldviews. Nature is described and understood in *general* terms (in terms of a worldview). The epistemological rupture of modern technoscience represents the second moment: the moment of negativity (M_2), where poetic experience is replaced by the technical prose of acronyms, neologisms and mathematical equations, generated by experimental research practices. Science gives rise to *particular* ways of interacting

[2] Cf. Engels' view on science as a process of "moulting", a shedding of protective (immunising) ideologies, a metaphor he adopted from Liebig (discussed in the previous chapter).

with the world. The normal *modus operandi* of technoscience consists in tearing things apart. The active negativity of technoscience is not only relentless, but also self-destructive, constantly spoiling its own achievements by criticising and negating temporary insights, replacing them with more convincing and *concrete* results. Finally, genuine scientific breakthroughs occur when rationality becomes "surrational", i.e. when imagination joins forces with advanced mathematics and critical reflection (M_3) to produce astonishing results in the context of research practices which are inherently *philosophical* (e.g. quantum physics), albeit not in the traditional sense of the term. Thus, technoscience discloses a surreal world which seems dramatically at odds with natural intuitions.

According to Bachelard, technoscience is driven by a dialectical logic. To elucidate this, I will zoom in on Bachelard's use of the term "dialectics", reading him aloud as it were. I will discuss those publications in which the concept of dialectics is explicitly addressed, namely *Atomistic Intuitions* (published in 1933), *The New Scientific Spirit* (published in 1934), *The Formation of the Scientific Mind* (published in 1938), *The Philosophy of No* (published in 1940), *Applied Rationalism* (published in 1949), *The Rational Activity of Contemporary Physics* (published in 1951) and, finally, *Rational Materialism,* published in 1953 (the year of the discovery of DNA, but also the year in which Jacques Lacan inaugurated his famous Seminar).

Psychoanalysis and Dialectics

In *Atomistic Intuitions* (1933/1975), Bachelard presents the atom as a prototypical object of technoscience, precisely because it is an "impossible" object (from a traditional philosophical point of view), giving rise to multiple contradictions and anomalies. First of all, Bachelard agrees with Hegel that the concept of the atom as envisioned by ancient and modern atomists was a *metaphysical* concept, developed on the basis of intuitions, such as the image of particles of dust randomly floating in air (M_1). Until the dawn of modern chemistry, the atom was an imaginary entity, and ideas concerning the shape, surfaces, qualities and interactions of atoms were products of speculation, imagination and free association. At the same time, the concept concurred with practical experience, notably the experience that, notwithstanding human effort and labour, everything inevitably returns to dust: to the inchoate chaos of pulverisation. All is vanity, and sooner or later, everything will be disrupted and *negated* (M_2). Therefore, Aristotle's conception of a thing as a synthesis of form and matter was *not* a primary intuition, but the *result* of a dialectical process of working-through (M_3, p. 24). Aristotle's concept was the negation of the negation, i.e. a refutation of the atomistic idea that reality is *nothing but* atomic particles floating and temporarily coalescing in a void. For Aristotle, a living organism (as a consistent, organised, self-sustaining and self-reproducing entity) *is* in itself an irrefutable negation of ancient atomism.

For Aristotle, moreover, the concept of a void (a vacuum) was an ontological oxymoron. Modern science allegedly demonstrated that (in contrast with Aristotle's teachings) a vacuum *can* exist. Yet, as Bachelard emphasises: *not* "in nature". The modern vacuum is an artefact, created with the help of technical contrivances (such as the air pump). Such a vacuum is a technical (unnatural) state, and this entails an important lesson. According to Bachelard, technoscience does not study nature directly. A laboratory is an artificial setting where man-made phenomena are produced and studied under technological conditions.

It was only in the twentieth century that the atom (initially a metaphysical entity, giving rise to incompatible and contradictory interpretations) became truly an object: an object of technoscience. Via a dialectical interaction between advanced technology and advanced mathematics, technoscience revealed that atoms are *not* material substances in the traditional sense of the terms (minima of matter), but composed of subatomic particles with wave-like properties, vibrating and oscillating in a void. Moreover, the structure of atoms can only be explored with the help of technoscientific contrivances, which themselves should be considered as reified theorems: embodying theoretical convictions. As Bachelard would later phrase it, the atom is not a material object, but a "sur-object", constantly hovering between theory and experience, between noumenon and phenomenon, the result of dialectical processes of interaction (not only between particle and wave, but also between observation and computation). In "empirical" technoscience, moreover, the moment of "observation" is often compressed to a minimum (a fraction of a second). Therefore, traditional metaphysics should give way to a meta-*micro*physics, equipped to explore this dialectical *interaction* between advanced technology and advanced mathematics, between "observation" and computation.

This idea is taken up in a subsequent publication entitled *The New Scientific Spirit* (1934/1973). According to Bachelard, the "spirit" of technoscience vindicates the validity of the Hegelian conviction that *the real is rational*. The new scientific spirit (= the spirit of technoscience) is the result of a dialectical "rapport" between scientific reality (technology-mediated observations) and computational rationality (p. 12). The spirit of technoscience is relentlessly self-critical and not discouraged by experiences of opposition or negation. Rather, the spirit of technoscience is bent on putting its theoretical convictions to the test, in order to learn from experience. A technoscientific trial is neither purely phenomenological (descriptive) nor purely rational (apodictic), but involves a dialectical interplay between the rational and the real, mediated by technoscientific thinking as reified in technoscientific contrivances. Research instruments are technical materialisations of ideas, and what a technoscientific experiment aims to achieve is the *realisation* of a noumenal idea in the form of a technoscientific phenomenon: the coming-into-being of a rational world under radically technological conditions. Thus, technoscience is basically a form of dialectics, albeit more instructive than the "ponderous dialectic" of traditional philosophy (p. 18).

Bachelard discerns an epistemological rupture in philosophy around the year 1800, separating Kant from Hegel. While Kant constructed his epistemology on the basis of Euclidean geometry, it is no coincidence that the emergence of non-Euclidean geometry coincided with the development of Hegelian dialectics, Bachelard argues. Non-Euclidean geometry was initiated by Gauss (in 1813), Schweikart (in 1818) and others in the beginning of the nineteenth century, precisely when Hegel was developing his views. Contrary to apodictic and deductive Euclidean geometry, non-Euclidean geometry is a profoundly "dialectical" endeavour, Bachelard contends (p. 24). Non-Euclidean geometry exemplifies the dialectical spirit at work in technoscience, because it shows how scientific breakthroughs are instigated by instances of crisis (the scientific revolution as the negation of the negation, the sublation of a crisis).

A similar idea is developed in *The Formation of the Scientific Mind* (Bachelard, 1938/1970). Again, Bachelard emphasises the *dialectical* nature of technoscientific experience. Driven by suspicion with regard to established, intuitive views (M_1), technoscience sets out to study phenomena systematically, under different (contrasting) conditions (M_2, p. 16). Alchemy differs from technoscientific chemistry in that it aimed to verify intuitive understandings (under the sway of archetypes). Therefore, it was a research practice destined to interminable failure: the chemical version of what Hegel refers to as an "unhappy consciousness" (p. 49). It was only by systematically comparing contrasting experiences and by exposing intuitive and imaginative convictions to refutation and negation (M_2) that modern science eventually produced concrete, valid and replicable results (M_3).

The dialectical logic of technoscience is explored in depth in two subsequent publications, first of all in Bachelard's *Philosophy of No* (1940/1949). Philosophy should not opt for an apodictic stance, Bachelard argues. Rather, he agrees with Hegel that the owl of Minerva takes flight at dusk. For the hour of philosophy to ring, technoscience must already have done its work. And work (labour) is a dialectical experience, a dialectical interaction with matter and reality, a dialectic of action versus reaction, of transformation versus resistance, etc. (cf. Bachelard, 1948). This same dialectic is discernible in technoscientific labour. Scientific insights result from a dialectical interplay (1940/1949, p. 5) between two apparently contrasting poles, namely (mathematical) *rationality* and (technologically modified) *experience*, between the *noumenal* and the *phenomenal*, the *a priori* and the *a posteriori*. In other words, technoscientific experience is a *dialectically structured form of experience*, where primary observations are systematically exposed to contrasting conditions on the basis of rational predictions. Starting from *general* principles, technoscientific phenomena are exposed to *particular* conditions in order to acquire *concrete* results (p. 4). Technoscientific research is the *realisation* of an idea, evolving into a research program (p. 6). Likewise, there is a dialectical relationship between theory and application, for application means: exposing theorems to unexplored circumstances, to "otherness", in order to incorporate the results of these experiences into the body of knowledge (p. 7). The spirit of technoscience entails a relentless process of self-transformation, with new experiences *negating* previous experiences – hence the title, for the dialectical logic of technoscientific experimentation implies that new experiences negate (say "No" to) previous ones (p. 9).

The role of technoscientific instruments is crucial here. A thermometer, Bachelard explains, is already the materialisation of a theorem, while the use of thermometers drastically affects the scientific ego's way of being-in-the-world. Such instruments reflect an awareness of the finitude, the inherent deficits of our natural sense organs. They symbolise a "No" to non-validated forms of experience. This "No" does not imply that technoscience equals nihilism, however. Quite the contrary, Bachelard argues, because the end result of the dialectical process is something positive and rational, – or rather: "sur-rational", for it results in opening up the surrealistic worlds of contemporary technoscience, disclosing the noumenal, molecular structures of what in Kantian philosophy is diffusely referred to as the thing-in-itself or "substance" (p. 59), thereby enabling a dialectical turn in philosophy. Technoscience is profoundly dialectical and non-Kantian, saying "No" to the either–or of binary thinking (to Kantian dichotomies such as theoretical versus practical philosophy, the noumenal versus the phenomenal, the a priori versus the a posteriori, waves versus particles, and so on). Infected by technoscience, philosophy becomes transformed into dialectical thinking, or *genuine* thinking, resulting in Bachelard's key adage: "dialectiser la pensée!" (p. 17).

According to Bachelard, technoscience (contemporary chemistry for instance) is decidedly non-Kantian. Spectroscopy is a dialectical research field studying the *interaction* between matter and energy, particles and waves, etc. An electron, for instance, is not a "substance", it is a *dialectical* entity (p. 63), hovering between noumenon and phenomenon, between particle and wave. The logic of technoscientific thinking is profoundly dialectical (p. 105 ff.), subverting the law of non-contradiction (the binary logic of either–or), while in physics and chemistry the focus of intentionality is displaced from objects to sur-objects (atoms, electrons, hydrogen bonds, etc.). Again, although the philosophy of technoscience says "No" to many tenacious philosophical convictions, we should not see it as mere *negation* (p. 135). There is a positive result, namely knowledge concerning sur-objects, where the noumenal and the phenomenal, advanced mathematics and technoscientific experience coincide.

Whereas Bachelard posits an epistemological divide between Kantian epistemology and the dialectical philosophy embodied in technoscience, he is somewhat ambivalent when discussing the relationship between the dialectics of technoscience and Hegelian dialectics. On the one hand, he stresses discontinuity between the two, albeit on the basis of a (remarkably) crude understanding of Hegelian dialectics. Whereas (according to Bachelard) Hegelian dialectics proceeds from "thesis" via "antithesis" to "synthesis" (p. 135), technoscience rather sees thesis and antithesis as "complementary" (p. 136). Precisely this, one could argue (seeing binary opposites as complementary moments of a comprehensive approach), is what is at stake in Hegelian dialectics. In other words, when it comes to fleshing out the profile of the dialectics of technoscience, we notice a remarkable but unfortunate unevenness between Bachelard's acute understanding of the dialectics of technoscience compared to his rather crude understanding of and limited familiarity with Hegelian dialectics. To the extent that our understanding of the latter becomes more elaborate, however, the continuity between Hegelian and technoscientific dialectics becomes increasingly pronounced. And indeed, Bachelard himself agrees that philosophical and technoscientific dialectics seem to approach one another more and more closely – here, Bachelard even uses the word “approchement” (reconciliation, p. 136). In technoscience, for instance, a negation does not merely imply opposition. Rather, the opposite poles continue to be “in contact with” each other, and the negating position even “includes” or “envelops” what it negates (p. 137), – for instance: the concept of the atom includes both positive and negative components, while non-Euclidean geometry can be seen as negating, but also as *including* (sublating) Euclidean geometry.

In *Applied Rationalism* (1949/1962), we encounter a more developed view on the relationship between Hegelian dialectics and the inherent dialectics of technoscience. Some of the themes already discussed in previous publications are taken up again. For instance, Bachelard again stresses the importance of precision instruments in combination with surveillance, explaining how the latter plays a double role. Not only individual researchers, also established methodologies are put to the test by permanent surveillance (by the Über-Ich of technoscience, p. 80). Therefore, technoscientific research is always work-in-progress. It is an *active* philosophy, a philosophy of the Servant, a philosophy that *works*: a *hormology* (where the Greek term ὁρμώ / ὁρμαώ – means to arouse or to excite, p. 100). For indeed, technoscience works like a hormone: arousing philosophical reflection. Technoscience entails an epistemological rupture in philosophy, replacing a crude and abstract metaphysics with an advanced and validated one. To achieve this, philosophy must become acutely aware of what is happening in contemporary technoscience. For instance, Hegel is complimented for having understood polarity as an inherent dimension of matter as such (p. 139). This is confirmed by current insights into the polarity of matter (the dialectical relationship between electrons and protons in modern chemistry for instance, or between electron and positrons in particle physics).

The disclosure of the noumenal dimensions of energy and matter is only possible through the use of advanced technologies such as spectroscopy, studying the *interaction* between matter and electromagnetic radiation. Therefore, spectroscopy is a philosophical or even a *dialectical* technology (p. 103), supporting a noumenal approach to technical phenomena, allowing us to enter a surreal world which is far beyond the constraints of Kantian epistemology. Technoscientific contrivances are reified theorems, concrete materialisations of philosophemes (p. 103). Edison’s electric light bulb, for instance, is an abstract-concrete object, a product of technoscientific *thinking* (in Hegelian terms: a concrete universal). All technoscientific objects are bi-objects (p. 109), Bachelard argues, both phenomenon and noumenon (p. 109): a condensation or convergence of ideas giving rise to new ideas. And while Schelling deplored that phenomena were obfuscated by the technological dimension of technoscience,[3] Hegel appreciated the hard, experimental work involved in moving from mere observation (the phenomenal) to genuine insight (grasping the noumenal, the inherent concept). Technoscience results from the dialectics of applied rationality and advanced technology, in the form of precision instruments.

[3] “Die Lehre von der Elektricität beinahe mehr eine Aufzählung der Maschinen und Instrumente, die man zu ihrem Behufe erfand, als eine Erklärung der Phänomene” (cited in Bachelard 1949/1962, p. 153).

It is a synthesis of the spirit of geometry and the spirit of finesses. Technoscience is the dialectics of master and disciple *in action*, with the disciple functioning as the servant or worker (the ego of science), while the master provides supervision (as the scientific super-ego). The dialectic of master and disciple often becomes reversed, however. In a laboratory, a young researcher can easily become the master of his master. Eventually, in technoscience, the noumenal is captured in symbolic terms, in terms of equations.

In *The Rational Activity of Contemporary Physics* (1951) Bachelard once again presents technoscience (in this case: contemporary physics) as an *active dialectic*, while Bachelard focusses on the role of technology in exploring the *dialectical interaction* between phenomenon and noumenon, between epistemological obstacles and methodological interventions. The wave-particle dispute in elementary particle physics is presented as an exemplification of such a dialectic, resulting in a comprehensive view in which both aspects are acknowledged as moments, in close connection with the insight that energy is fundamental for understanding matter in itself.

Finally, some new insights are added in *Rational Materialism* (1953), published in the year of the discovery of the structure of DNA, so that, not coincidentally, the transition from chemistry to biochemistry and molecular biology is discernible in Bachelard's book as well. The philosophy of technoscience, Bachelard argues, remains a *materialist* philosophy, but one whose understanding of matter is profoundly instructed by the results, the spirit of contemporary research. Chemistry is presented as a *dialectical* science (p. 6), as "*dialectical materialism*" even (p. 6). An epistemological rupture separates this radical (dialectical) philosophy from crude and metaphysical materialism, as defended by philosophical predecessors (from ancient atomism up to modern times). Moreover, technoscience is a collective endeavour. In technoscience, individualism became an obstacle, an anachronism.

Special attention is given to *practical* dialectics, notably metallurgy. Metallurgy, Bachelard explains, was an *active dialectic*, the first *dialectical materialist* technology in fact (p. 72), involving separation and recombination of metals, while purity was not the starting point (a given), but a result. Metallurgy entails a movement from primary substance (i.e. inchoate ore, M_1), via isolation and purification (M_2) up to synthetic recombination (M_3), where the latter can be considered as a rational form of creativity. Rather than dallying with abstract conceptions such as "substance", philosophers should devote more time to studying the novel questions emerging in technoscientific research. Notably Hegelian philosophers are addressed. They should examine the *dialectics* entailed in technoscientific practices, for instance practices involving technoscientific symbols and equations (p. 135). Together, philosophical and technoscientific approaches may result in a "dialectics of the electron", examining it from multiple (allegedly incompatible) perspectives, as a wave *and* as a particle, as a chemical *and* as a quantum physical phenomenon (p. 138), as a scientific *and* as a philosophical object.

Bachelard explicitly discusses the hydrogen bond (–H···), – which played such a crucial role in the discovery of the double helix –, as an example of a phenomenon which is to be studied dialectically, from multiple (contrasting) perspectives: by questioning intermolecular bonding (quantum physics), intramolecular bonding (chemistry) and the molecular structure of proteins and other biomolecules (molecular biology). As a result of this displacement (from physics via chemical processes to the chemistry of life), experiences and insights which initially seem incompatible can be conjoined, while research into the role of the hydrogen bond in cell physiology becomes increasingly important. Indeed, we witness the emergence of molecular biology as a merger of quantum physics, biochemistry and cell biology (p. 140). And research into the hydrogen bond in molecular biology is not a mere "application", but a positive and synthetic research field in its own right. The hydrogen bond is an example of the kind of problematic which a new "phenomenology of the spirit" (in the Hegelian sense) should aim to address (p. 140). Indeed, the "spirit" at work in contemporary chemistry has important lessons for "Hegelianism", precisely because molecular biology is a "dialectical" science, outlining how the biomolecules of life result from a dialectical interaction, not only between energy and matter, but also between nucleobases and nucleic acids, with the hydrogen bond (–H···) acting as intermediary. Indeed, in terms of Hegelian dialectics, DNA is the outcome of a syllogism. The syllogism of electrophysiology as explained by Hegel (as an interaction between base and acid, with water acting as intermediary, and resulting in salt as product) resurges on the micro-level of biomolecular research (where nucleobases and nucleic acids produce DNA, with the hydrogen bond as intermediary). And this, Bachelard argues, calls for a meta-micro-physics (to replace traditional meta-physics).

The Year 1953

Although (to the best of my knowledge) Lacan nowhere explicitly refers to Bachelard, it is clear that Bachelard must be considered one of Lacan's key "precursors" (Eyers, 2012, p. 320), if only because Lacan shares Bachelard's emphasis on the importance of the "formation" of scientists (both rigid and practical) as well as his emphasis on the importance of formalisation and symbolisation (e.g. the use of mathematical, physical and chemical symbols as a decisive feature of technoscience). When Lacan speaks about the "formation of the individual" (1938/2001), he uses a phrase which echoes Bachelard's conceptions concerning the "formation" of the scientist. And when Lacan speaks about fire as the real ("le feu, c'est le réel", 1975–1976/2005, p. 121) we are reminded of Bachelard's *Psychoanalysis of Fire* (1938/1949) where he explains why fire as a primordial phenomenon no longer constitutes a valid object of technoscientific research. While fire (for instance: a hearth-fire) invokes multiple imaginary associations (childhood reminiscences, Hoffmannesque stories about alchemists in front of their furnaces, etc.), modern science relies on symbolisation (structural formula, chemical equations, and the like) to disclose the noumenal dimension of processes such as combustion and corrosion. As indicated, however, the question of this volume is not who influenced (or polemicized with) whom. What is at stake is what we may learn from Bachelard's and Lacan's way of practicing psychoanalysis of technoscience.

1953 was a remarkable year for various reasons (Zwart 2020b). It was the year in which the second Kinsey report ("*Sexual Behaviour in the Human Female*") was published, the Mount Everest was conquered, and the first colour television went for sale. And it was also the year in which Michel Foucault awoke from his metaphysical slumber by reading Nietzsche. For technoscience, it was the year when Watson and Crick, building on the X-ray crystallography work by Rosalind Franklin and Maurice Wilkins, discovered the structure of DNA. Finally, it was the year in which Jacques Lacan presented his *Discourse de Rome* and launched his Seminar. DNA research and Lacanian psychoanalysis have something in common. Lacanian psychoanalysis used to be referred to as "structuralism", and although this label went out of fashion, the term indicated how (in linguistics for instance) combinations of elements convey meaning (information). In life sciences research, crystallography likewise reveals how all living substances are composed of biomolecular structures (crystals) and how these structures (the "forms" of living beings) convey information (Gilead, 2020). Structures are forms which *inform*, and crystallography is a basic technology for molecular biology, the biological version of "structuralism".

Jacques Lacan: Formalising the Hegelian Syllogism

Although the intellectual vocation of Jacques Lacan was to instigate a "return to Freud", Hegel's dialectics of master and servant may actually be regarded as the initial starting point of Lacan's intellectual trajectory. Indeed, both in his *Écrits* and in his *Seminars*, Lacan seems to serve two Master, both Freud and Hegel, although the latter sometimes speaks as a hidden Master's voice. Like in the case of Bachelard, I will explicitly zoom in on the dialectical dimension of Lacan's oeuvre: the continuities and differences between dialectics and psychanalysis.[4]

Lacan acknowledges his indebtedness to Hegel on multiple occasions, claiming for instance that it is impossible for psychoanalysis to ignore "the structuring moments of Hegel's phenomenology", e.g. the dialectic of master and servant, the figure of the beautiful soul and the interrelatedness between the constitution of the object and the formation of the subject (Lacan, 1966, p. 292). According to Lacan, a point of divergence between both approaches is that psychoanalysis aims to

[4] In their best-seller *Fashionable nonsense*, Sokal and Bricmont (1998) framed Lacan (together with many other, mostly Francophone authors) as an "intellectual imposture". Rather than entering into this (repetitive) debate myself, to which already a huge amount of literature has been devoted, I prefer to move beyond the "science war" polemics and to opt for a "positive" approach, by indicating how Lacan not only had a thorough grasp of what was happening in science, but also made important contributions to philosophical reflection on technoscientific developments. Overall, rather than entering into discussions (often quite polemical) with critics of continental philosophy, the objective of this volume is to show what a continental approach amounts to, and to outline what it has to offer (*via positiva*) for practicing philosophy of technoscience today.

decentre the subject from self-consciousness (p. 291), but one may question of course whether such a decentring of individual subjects vis-à-vis self-consciousness or spirit deviates that much from Hegel's own conception.

Lacan commented on the dialectics of master and servant on various occasions. Initially, the servant acknowledges the supremacy of the master. Instead of challenging the latter's authority, the servant willingly relinquishes his own autonomy, opting for an attitude of devotion and servitude. Following the intervention of the master, the servant is put to work, in the interest of the master. Rather than aspiring to become a master themselves, servants accept a subordinate position, seeing their dependency as a prerequisite for survival: as the servant is not an owner, and needs to earn a living.

The master owns the means of knowledge production and the power relationship between master and servant is mediated by technology. An interesting example of this is mentioned by Lacan in his *Écrits*, when he argues that contracts require a considerable level of precision when it comes to time management. Therefore, dialectically speaking, it is no coincidence that Christiaan Huygens invented his pendulum clock in 1656 (patenting it the following year), because this clock embodies the symbolisation of the temporal real by technoscience. From now on, it is possible to determine and define the working day independently from natural phenomena such as dawn and dusk: a form of "liberation", and an important turning point in the shift from quality (craftmanship) to quantity (machine-labour). Since then, Servants are put to work in a universe of discipline and precision (Lacan, 1966, p. 313). As Marx already pointed out, whereas in pre-modern rural villages the difference between day and night (between production and reproduction) had been a matter of custom, during the industrial revolution all natural boundaries were shattered and clock-time forced human subjects to negotiate, with "Talmudic acumen", the exact meaning of the signifiers "day" and "night" (Marx, 1867/1979, p. 294). The servant's servitude also produces a particular form of jouissance, however, handling the master's property, guarding the master's legacy, in an efficient manner. Yet, a dialectical dynamic was bound to unfold, eventually subverting the situation in the sense that the sway of the master becomes increasingly dependent on the work of the servants, while the latter become increasingly skilful. The servants know that the master is mortal, moreover, and while the clock is ticking, they only have to wait. Time is crucially important in technoscience, where time is often quantitatively represented by the horizontal axis of the coordinate system, invented by Descartes, – although when Descartes published his discourse on method (in 1637) it would take quite a while before the first reliable pendulums arrived (Lacan, 1954–1955/1978, p. 94, 343). This (the absence or presence of contrivances of exactness such as pendulums) defined the difference between Descartes' thought-experiments and the scientific experiments conducted by Huygens and Newton. Without exactitude, no exact science, and no machine labour.

In Lacan's oeuvre, the position of the master is indicated with the help of the Master signifier, positing the master as primal subject, the initiator of the process (S_1). While the Master, after a single powerful, decisive intervention, devotes himself to contemplation, his style of thinking contrasts with the type of knowledge produced by servants: *know-how*, basically ("savoir-faire", Lacan, 1969–1970/1991, p. 21). The master (the gentleman-philosopher) is initially in control. He appropriates the servant's practical knowledge and transforms it into abstract knowledge (e.g. "pure", Euclidean geometry). The desire to acquire "pure" knowledge (cleansed of everything reminiscent of reality and application, of "dirty hands") is a typical phantasy of the privileged classes. Lacan points to the dialogue between Socrates and the slave Meno, where Socrates acts as a benevolent gentleman-teacher, granting the illiterate slave a crash course in Euclidean geometry, only to discover that the slave already *knows* his geometry, albeit in a practical, hands-on manner. The knowledge of the servant has been appropriated by the master, who transforms it into apodictic, deductive knowledge, and now purports to give it back "for free", in the form of education (Lacan, 1969–1970/1991, p. 22).

In the end, the practical knowledge of the servants will prove much more powerful and effective compared to the lofty contemplations of the master who, instead of really interacting with and transforming nature, develops a worldview, i.e. an imaginary vision of nature (e.g. the phantasy of a spherical, harmonious cosmos). Eventually, the supremacy of the master (S_1) will by subverted by the practical know-how of the servant (S_2), so that in the end S_2 will come to occupy (usurp) the position of the agent: the one who is in control. The power of the master is subverted.

The emancipation of the servants does not stop there, however. Instead of relying on the concepts coined by the master, servants explore and interact with nature more directly, with the help of technical contrivances. The master's apodictic views are suppressed, as former servants increasingly rely on hands-on, practical interactions with nature, developing powerful tools to effectively manipulate and modify natural objects: the birth of the experimental method. Exegesis increasingly gives way to experimental work (manipulating nature). Thus, former servants assume mastery over the situation. They become scientific agents, while the metaphysical pontifications of the master become a superfluous burden.

This is evidently in line with Hegelian dialectics. Initially, the Master is the primary *agent* (first position), spokesperson of a general, apparently neutral and stable worldview, while the servant is the *other* (second position), inciting the idle master into activity (disrupting his *otium*), but also the one to whom the master addresses his directives. In the course of history, the former servant inevitably emancipates into a qualified expert, so that the master becomes increasingly dependent on the know-how of the servant. Their interaction results in concrete *products*, which will initially be appropriated by the master. There is a fourth position involved, moreover: the *disavowed truth* of the master's discourse, namely the disconcerting experience that the Master himself is an alienated, doubting and divided subject as well (Hegel's unhappy consciousness). When this is recognised, the former servant emancipates by adopting (usurping) the position of the agent.

Lacan uses short-hand symbols to refer to these four variables: the master subject (S_1), the knowing servant (S_2), the divided subject (*$*) and the object of desire (*a*). These four variables can be inserted into a quadrant, consisting of four positions (agent → other → product → truth), arranged within a quadruped scheme:

Agent	Other
(disavowed) Truth	(unintended by-) Product

Notice how closely Lacan follows Hegel's syllogism of agent (A), other (O) and product (P) (agent → other → product) that was discussed above (§ 2.12). Eventually, the dialectical process will reveal the (initially obfuscated) truth (T) of a particular constellation.

The interactions between these four variables, in four different positions, – albeit in a fixed sequence: agent → other → product → truth (AOPT) –, give rise to four "discourses".

Discourse of the Master

First of all, the discourse of the Master, already outlined above:

S_1 (A)	S_2 (O)
$ (T)	*a* (P)

Here, the master acts as *agent* (upper-left position), initiating the process and dominating the discourse. The master addresses the servant as the *other* (A → O). The servant is the recipient of the master's instructions, for instance by acting as a scribe or as an artisan (upper-right position). Although the master may have his moments of uncertainty and doubt, and will most likely be a desperate subject himself, this truth ($) is disavowed and obfuscated (pushed into the lower-left position) so that (formally at least) the authority of the master remains unquestioned. The servant produces the object *a* as product (P), but this object also indicates a loss, because it will be appropriated by the master, who will enjoy it, so that for the Servant, it is a "lost object", and the process of production has to be resumed to satisfy the demands of the master. The relationship between servant (S_2) and object (*a*) can be defined as "restrained desire" (desire kept in check: O → P). Although the servant's labour may be duly rewarded (in the form of a salary for instance, to earn a living), the surplus value as product (*a*) will be enjoyed and consumed by the master. Eventually, however, the servant will become aware of the master's dependency on his skills and products, and will realise that this is the obfuscated truth of the situation (P → T). This awareness, this consciousness, is the first step in the process of the servant's emancipation. In the end, the servants themselves will usurp the position of Agent (S_2 moving to the upper-left position), and the quadruped scheme will take an anti-clockwise quarter-turn to the left, resulting in a revolution, in the literal sense of the term. Thus, the master's discourse and its outcome is Lacan's equivalent of Hegel's dialectic of master and servant.

We may easily recognise a dialectical *syllogism* in this scheme. The process starts with the master as *agent* (M_1), allegedly an independent subject, fully in control. The encounter with a submissive *other* (S_2), who subjects himself to the master in order to survive, to *earn a living*, gives rise to servitude as a particular form of interaction. For instance, the master may be in charge of a library, a scriptorium, a workshop designed for producing copies of authoritative documents, while S_2 may enter the situation as a novice, an anonymous scribe. The setting generates textual products, but although the scribes will be offered room and board (a living) for their efforts, the products (valuable copies) are appropriated by the master and accumulated in the library. Until the library is set to fire (as eventually happens to libraries, notably in times of revolution). Hume's advice, as a philosopher of Enlightenment, concerning the metaphysical volumes of the Master was: commit them to the flames, allegedly an act of cleansing and liberation (Zwart, 2019a, p. 68).

Thus, an antagonism is at work here, which will become increasingly evident. There is a hidden truth involved, the desire of the tormented master to remain in control of the situation and to appropriate the valuable outcomes of the process. Tensions will arise to the extent that the dexterity of the servant, in interpreting and reproducing authoritative documents for instance, is bound to progress in the course of time. The antagonism (the truth of the situation) eventually manifests itself, so that the syllogism fails to reach its proper end, giving rise to multiple obstacles and symptoms. As Bachelard already explained, in the context of intellectual collaboration, disciples may eventually become masters, in view of their dexterity and craftmanship, giving rise to disputes over authorship or intellectual property rights. Dissatisfaction with this type of discourse eventually results in the emancipation of the former servant, who now claims his intellectual independence and aspires to become the agent (A).

The predicaments of the servant are exemplified by Erasmus of Rotterdam as a case history. Evidently, he was not a mere scribe (copying documents in a more or less mechanical fashion) but a paragon of classical scholarship, preparing critical editions on the basis of his superb mastery of Latin and Greek. Yet, to realise his humanist scholarly idea, he still needed a technological base: the early modern printing press, as a replacement of the medieval scriptorium. In the case of Erasmus, this material base was provided by the printing house owned by Johann Froben of Basel, where Erasmus actually lived for many years, in close proximity to the process of printing the works he wrote or edited. As Lacan convincingly argued, the constitution and reformation of the early modern subject depended on the correctness and proliferation of the signifier. It was by modifying the relation to the signifier – e.g. by optimizing the procedures of exegesis and editing – that the moorings of the human condition were altered (Lacan, 1966, p. 527). But the signifier needed to be a reliable, i.e. *printed* one, edited by qualified scholarly experts, and printed by professional artisans.

Eventually, this dialectical process of emancipation gave rise to what came to be known as the scientific revolution. Until then, servants (scribes like, say, Thomas a Kempis) had obliterated themselves by devoting their time to reading, copying, editing and commenting authoritative texts (e.g. the Bible, Church Fathers, etc.), or documents written by Master thinkers (a position which, in medieval scholarship had been allotted primarily to Aristotle). Now, however, the former servants decided to study and interact with their object of research more directly. Rather than commenting on the Scriptures or on Aristotle's *Physics*, the ambition now becomes to engage in technoscientific research oneself. Research contrivances (scientific instruments) replace the master as intermediary between subject and object. This does not mean that the researcher at work is now fully independent, quite the contrary. Intricate machinery is required to come to terms with the elusive objects of research. Research requires a material base and instruments have to be funded.

A fascinating early modern example was already described in the previous chapter: Tycho Brahe's astronomical observatory Uraniborg. Brahe decision to focus on astronomy had been triggered by the sudden emergence of an "impossible object" (*a*), a *nova stella*, an oxymoron in a world where celestial bodies represented unchanging eternity. Brahe's "impossible" *object a* provided a window (an opening) into the enigmas of the starry universe. Brahe's ambitious and extremely expensive Uraniborg-project was completed in 1580 and sponsored by King Frederick II of Denmark (the monarch, acting as master). During the early-modern period, absolutist monarchs often functioned as funders of research. Thus, the researcher was working for a master. A dialectical view on the history of technoscience zooms in on what, in normal discourse, revolving around scientific heroes and their ideas and intentions, tends to be obfuscated: the power relationships to which these egos of science are actually subjected: the relationship between knowledge, power and desire. In the case of Tyche Brahe, much time and energy were spent on prognostications, using celestial harmony to seek for guidance in tumultuous times (Pannekoek, 1951/1961). These prognostications were comparable perhaps to how nowadays politicians consult the Wall Street stock exchange before making difficult decisions. The observatory functioned as a kind of eye which allowed only small, quantifiable samples of reality to enter. The products of this dialectical interaction reflect the antagonisms at work: Europe's most advanced and expensive observatory, manned by the last of the naked-eye astronomers, who published a drastically renovated astronomy in combination with prognostications, in short: Tycho Brahe as a divide subject, mid-way scientific revolution and servitude.

S_2 (Tycho Brahe as ego of science, as homunculus inside his observatory) as agent: A	*a* (the impossible object or oxymoron, *nova stella*) as other: O
S_1 (Supported by King Frederick II, the absolutist monarch); servitude to the Master's worldview as (disavowed) truth: T	*$* (Tycho Brahe as a divided subject; unintended by-product): P

All this is part of the early modern history of technoscience, however. Let us now, after these concise historical detours, return to psychoanalysis, that is: to the moment when psychoanalysis was born, during the 1890s, when the former servants had fully emancipated and university discourse was allegedly in full swing, exemplified by physiology as a research field (Freud's initial field of training).

The Emancipation of S_2 – The Case History of Ivan Pavlov

In the nineteenth century, funding of research had become a responsibility of the state. In the course of the scientific revolution, the syllogism of the knowledge production had given way to what Lacan refers to as university discourse:

S_2	*a*
S_1	$

The experimental expert (S_2) is now the *agent*, taking the initiative, initiating the process, relying on technical dexterity and expertise, designing and conducting experiments directed at addressing, questioning and capturing the object *a* (now in the position of *Other*) without any direct interventions from a Master. S_2 does not refer to *one particular* technoscientific brain worker, for research will often be conducted by teams, involving multiple trained experts, working together on the basis of division of labour. S_2 may be the head of a laboratory, but research managers are not Master in the Lacanian sense. They are qualified researchers, supervising other researchers, so that both research managers and their junior researchers find themselves in a precarious position as brain workers, the latter because junior researchers tend to be employed on the basis of temporary contracts, the former because the fate of the manager will depend on the performance of the laboratory as such (where clocks are always ticking).

Ivan Pavlov many perhaps serve as a telling exemplification of the new situation (Zwart, 2010). In four successive years (1901, 1902, 1903, 1904) Pavlov was nominated for the Nobel Prize in physiology or medicine, and each time the award committee confronted the same question: to what extent were the products of Pavlov's laboratory truly Pavlov's? The nominee had himself pronounced that his work was the achievement of his laboratory, operating as a knowledge factory. He had credited his co-workers for actually conducting the experiments on which his output was based. Did Pavlov's work represent his own original contributions to science, or was it merely a compilation of experimental dissertations (Todes, 2002, xiii)? Pavlov was a research manager rather than a solitary researcher, and his laboratory was a factory producing knowledge claims in a systematic fashion, a knowledge production line (Todes, 2014). Although Pavlov designed most of the trials and collected the research results to present them in books, papers and lectures, the actual experiments were conducted by "praktikanti" working in Pavlov's research facilities, hoping to complete their medical training in this manner. The interaction between supervisor and praktikanti resulted in numerous products, boosting the laboratory's reputation. In 1904, the Nobel Prize finally was awarded.

Jacques Lacan was interested in the case of Pavlov (a contemporary of Freud) for various reasons (Zwart 2018b, 2019a). Whereas ethologists describe animal behaviour in terms of response triggered by visual stimuli (the gestalt of a predator, a prey, etc.), Pavlov's research demonstrated how animals may function in a symbolic environment, where artificial signs trigger the production of bodily fluids. It is no coincidence therefore that Pavlov acknowledged the contributions made by his compliant dogs in his publications. Research implied intense collaboration, not only with praktikanti, but also with these animals. As Haraway (2008) convincingly argues, besides research assistants and animal caretakers, also the research animals themselves were "workers in the lab" (p. 71, 73). Both the people and their dogs laboured to produce knowledge under strained conditions. Rather than mere objects, they were partners in the research.

Whereas the qualified researchers conducted the experiment, the bodily fluids excreted by animals (saliva and gastric juice, produced in response to signals) functioned as object *a*. Pavlov made small openings (windows or fistulas) in the throat or stomachs of his animals to collects these secretions, so as to measure and analyse the samples as exactly as possible. Thus, saliva and gastric juice (slimy substances, regarded as detestable in normal life) became highly valuable entities, *products* produced by the animal-*other*. Although allegedly both humans and dogs participated voluntarily in the research, praktikanti were required to participate as a mandatory internship, while animal suffering was often involved. Ideally, animal laboratories are perfectly organised settings which satisfy all animal needs, thereby reflecting a modernistic, utopian ideal (Lacan, 1957–1958/1998, p. 461), a brave new world, a *Walden Two*, perfectly managed with the help of science and technology (1957–1958/1998, p. 463). This explains why the communist leadership (both Lenin and Trotsky) were firmly supportive of Pavlov's work: they saw his laboratory as a window into the future and as a model version of a future communist society. In reality, however, Pavlov's laboratory was not that animal-friendly at all. It produced animal suffering in various forms (as unintended by-product of the research), resulting in various kinds of symptoms (*$* as product). Pavlov even noticed "experimental neurosis" among his dogs (Lacan, 1966, p. 273; 1962–1963/2004, p. 72). His lab was a pathogenic environment, a totalitarian regime that cared for its animals but exploited their bodies as production factors, while eventually it was the research manager (S_2) who enjoyed the fruits of the dogs' labour, in the form of publishable and citable knowledge and, eventually, the Nobel Prize (the ultimate object *a*, awarded by the committee as "other", as forum, as final recipient of Pavlov's output). This entailed a process of displacement ("*Verschiebung*"), of denaturalisation and symbolisation (from fluids via publications to recognition).

The laboratory was a knowledge factory driven by desire, by a will to know, but also by a will to power, a desire to acquire behavioural control (Lacan, 1964/1973, p. 264; cf. Zwart, 2014): the truth of the constellation. In October 1919, Lenin allegedly paid a secret visit to Pavlov's laboratory to find out how the work on conditional reflexes might help communism to control human behaviour. The ultimate aim of communism was to improve and transform human nature. Although Pavlov was critical of communism, he accepted patronage by the Bolshevik regime. Lenin spoke of Pavlov's work as hugely significant for the revolution and Trotsky saw the production of an improved version of humankind as communism's great task, using current humanity as raw material. Pavlovian psychology became official doctrine and in 1949 it was formally declared that Pavlov had demolished "the Freudian house of cards" (Roudinesco, 1986, p. 53). On January 24, 1921, a formal Decree was published on Pavlov's research (Lenin, 1921/1965, p. 69), indicating that, in view of Pavlov's outstanding scientific services, which were of tremendous importance to the working people of the world, a special committee was established to guarantee the best conditions for his research. While his laboratory would be furnished with every possible facility, Pavlov and his wife would receive a special food ration (twice the number of calories of normal academic rations). Pavlov himself was thus addressed and treated as an experimental dog by the communist leadership, encouraging him to continue to produce knowledge. A specific signifier (the formally signed decree) was installed, signifying food (during a period of massive deprivation and starvation). Thus, a specific form of scientific work was singled out as being of strategic importance. Although the voice of totalitarian power (S_1) spoke from beneath the bar as it were, university discourse continued to function. In the case of Pavlov, the distance between S_1 and S_2 was maintained. Surveillance by Lenin and Trotsky operated from a distance, without direct interference in the experiments. In the case of Stalin, Žižek argues (2016/2019, p. 254), the proper dialectical tension between S_1 and S_2 collapsed – as exemplified by the Lysenko case.

University Discourse and Its Vicissitudes

This is how Lacan sees university discourse, a form of discourse which is not only found at universities, but has a much broader range of applications, for instance to explain the functioning of modern bureaucracies. The science manager (S_2) is focussed on things like quality indicators and impact scores (as object *a*), but these may become "perverse incentives", resulting in symptoms such as discontent or burn-out among exploited brain workers ($ as unintended by-product). Lacan defines communism as a form of university discourse operating on the level of the state. Currently, it is often claimed that, in the era of globalisation, all the world is becoming a laboratory: a global living lab, while all individuals function as research subjects, constantly producing data, – which basically means that the syllogism of university discourse has dramatically proliferated, has acquired an astonishing external validity.

S_2	*a*
S_1	$

The qualified expert or brain worker (S_2) is the agent, taking the initiative, designing and conducting the experiments, while outsourcing most of the activities – the actual experimental being-at-work of technoscience – to intelligent machines. This not only involves routine and menial activities, for contemporary technoscience relies on molecular precision and advanced computation, enabling us to gain access to weird, noumenal domains which are not part of human reality, from quantum oscillations to the genome, outside the human sensorium, existing independent from human consciousness, a nonhuman real which is not part of our reality (Žižek, 2016/2019, p. 33). Apparatuses enable humans to explore the real outside the scope of their experiential reality. The object *a* is now a weird, freak object, preferably on the molecular scale. Many servants may actually function as managers, principal investigators or departments heads, but as indicated, these managers are not Masters. Managers are workers, perhaps even workaholics, whose activity is driven by struggle for survival, – the pendulum is watching them. Their position may actually be quite precarious and the end of their career may always seem imminent, for instance in the case of disappointing results (a fall in the rankings). The Master is an invisible Master, pushed beneath the bar, but still quite persuasive (e.g. Lenin and Trotsky supporting Pavlov's work as a reinforcement of soviet ideology). In contemporary technoscience, the Master may operate as a hidden, anonymous Über-Ich, a relentless imperative (go on, produce more knowledge, never enough!), never satisfied with the performances of research managers and their teams, confronting them with a digital pendulum, a stock market of global research performance indicators, using advanced search robots to take count of all publications and citations, relentlessly pushing brain workers to produce more data, more papers, more results. Interestingly, funding agencies and university boards are currently becoming aware of the extent to which performance indicators such as *h*-scores may operate as perverse incentives, meaning that research activities become focussed on boosting rankings (e.g. of journals and universities) rather than on the "societal relevance" of the knowledge thus produced. But this will probably neither end the quest for comparative (competitive) metrics nor the hyperactivity of technoscience as a global enterprise. Metrices for "impact" and "diversity" are already proliferating.

Thus, like all four discourses, university discourse constitutes a syllogism, in the Hegelian sense of the term (from *agent* via *other* to *product*). The *agent* (the qualified expert: S_2) is challenged by and manipulates (challenges) *otherness* (i.e. the enigmatic object of research: *a*), and this process may result in various products, first and foremost in research papers: an anonymous type of output where a technical, anonymous form of authorship effectively results in the marginalisation of the subject (the "death" of the author). In university discourse, "it" speaks. As Nietzsche already argued, modern science entails the replacement of exceptional geniuses by armies of anonymous individuals (1980, § 547; Zwart, 2010). According to Nietzsche, a true scientist will endorse rather than deplore this anonymity as inevitable. For Nietzsche, a true scientist is not only someone who is willing to put his theories to the test, remaining susceptible to criticism, continuously on the alert not to deceive himself; for Nietzsche, the most important scientific virtue of all is self-denial. *Was liegt an mir!* It is not me that counts! For Nietzsche, this phrase summarises the core of the scientific ethos, the quintessence of being "in science" (1980, § 547).

His view was taken up many years later by Michel Foucault: "Qu'importe qui parle?" For Foucault, the most fundamental ethical principle of contemporary scientific discourse resides in a basic indifference towards authorship (1994, 789; Cf. Zwart, 2001). Science is, first and foremost, a discursive phenomenon in which author names serve as functional tools, notably in the context of information retrieval and quality assessment of research teams. In normal science, academic authorship comes very close to anonymity, and there is a certain moral quality in the stoical acceptance of this fact. Thus, rather than serving as a medium for self-expression, academic output entails de-subjectivation and alienation, until (in the extreme sense) the subject is reduced to something purely symbolic, an *h*-score for instance or an ORCID (a persistent digital identifier). This alienation or division ($) between the formal subject (e.g. the researcher as a kenotic cogito, stripped of all subjective content) and the actual, living, tormented subject (the researcher "as a person", desperately struggling to keep up with the academic pendulum), is an inevitable outcome or *product* of university discourse. The same alienation can be encountered in bureaucratic systems, as reflected in the impersonality of letters and reports written by civil servants (or their robots).

Experts as agents (S_2) realise their grounding conception through their work. Erring consciousness desires to become science. Initially, human beings are split, barred or erratic subjects ($), characterised by a propensity to err, to go astray ("Irre", in Hegel's terms, 1807/1986, p. 106), indicating that individuation, although aimed at reconciliation and realisation, remains a hazardous and interminable process. Knowledge production offers erring subjects a "ladder" (Hegel, 1807/1986, p. 29) to reach the standpoint of science, temporarily allowing them to function consistently, as subjects or egos of science ($\$ \rightarrow S_2$), as reliable producers of replicable knowledge. Desire is temporarily kept in cheque, and S_2 no longer experience themselves as tormented subjects. Yet, as indicated by the matheme or syllogism of university discourse, the end result is nonetheless a resurgence of despair ($ in the lower-right position). Notwithstanding the subject's hard work, the gap between truth and knowledge resurges, and the split recurs as an irreconcilable scar. The truth of university discourse is that a hidden metaphysical imperative (S_1) was pressing the subject towards verification, a process which eventually falters. The subjects experience the deficits and one-sidedness of the concepts they aspired to realise. Their insight was a mere moment in the history of knowledge, about to be superseded.

Thus, the place of truth (lower-left position) must likewise be understood in Hegelian terms, namely in the sense that a particular figure is the truth of another, preceding figure, and the exposition of its concealed latent structure (Žižek, 2016/2019, p. 217). University discourse is the inevitable successor of the discourse of the Master, because in the course of history, qualified expertise inevitably replaces reliance on authoritative documents (Aristotle, Genesis). Primal insights have to be verified through empirical labour and working-through ("hindurcharbeiten", Hegel, 1807/1986, p. 31), and thinking subjects must discern their guiding idea in what apparently refutes it, must absorb apparent otherness into the expanding system of science. At the same time, the spectral position of the Master remains the disavowed truth of university discourse: the apparently neutral position of qualified expertise (S_2) conceals a dimension of domination, a will to power, so that S_1 in the lower-left position refers to the hidden metaphysics at work, which must be brought to the fore and questioned. Otherwise, as Hegel argued, it will dominate us.

Within the constraints of university discourse, we can never completely rid ourselves of this hidden Master, this vocal spectre, except perhaps through elimination, but to do so we may have to sacrifice our own scientific career (accept that our existence as a *homo academicus* may be terminated). As long as we remain in science, in the field, the imperative remains in place. In other words, after the scientific revolution, brainworkers for whom the pendulum tolls are working harder than pre-revolutionary scholars who were serving a monarch. As Bachelard already argued, the scientific method is closely connected with surveillance. Performance indicators are reifications of the academic super-ego, precision instruments of supervision, a panopticon watching us (technoscience as a race against the clock, a relentless struggle for priority).

Thus, Lacan's scheme concurs with the schema provided by Hegel in the *Phenomenology of the Spirit*, situating subjects in their relationship to knowledge (Lacan, 1966, p. 793). The scheme positions the scientist as a subject (p. 794), indicating that science did not come into this world all by itself, but as a result of a scientific revolution, defined as an anti-clockwise quarter-turn of the quadruped scheme. According to Lacan, one important difference between dialectics and psychoanalysis (between Hegel and Freud) is that Hegel failed to acknowledge the importance of machines (1954–1955/1978, p. 94), but this is a questionable claim. Obviously, there can be no mechanics without machines (e.g. pendulums) and no chemism without machines, no electrolysis without technical contrivances, resulting in batteries and so on. Although Hegel's logic is about ideas rather than machines, developing a dialectics of technoscience is the inevitable next step as we have seen (Juchniewicz 2018), so that dialectics becomes sublated into *dialectical materialism*, as Bachelard argued, because that is what the inherent philosophy of technoscience essentially is: dialectical materialism. Still, precisely to bring this to the fore, dialectics and psychoanalysis complement one another.

In short, in university discourse, the intentionality of S_2 is focussed on *a*, endeavouring to integrate (process, domesticate, appropriate) this enigmatic, recalcitrant entity. This is in accordance with Marx's view of technoscience as the appropriation ("*Aneignung*") and transformation ("*Verarbeitung*") of the real. The "unique selling point" of experimental technoscience is precisely its focus on a particular (recalcitrant, enigmatic) entity, something surreal, a sur-object (Bachelard) rather than an object, a non-substantial entity eluding the subject, never really there, a stain-like form which, like in the case of anamorphosis, can only be made visible when looked at from a particular (technologically mediated) perspective (Žižek, 2016/2019, p. 83). Speaking from beneath the bar (from beneath the stage) is the normative imperative: go on, produce more knowledge, never enough! The activity (energeia) of technoscience is sustained by normative pressure.

A First Case History: The Majorana Particle

Allow me to elucidate this scheme with the help of a first case study. In particle physics, every type of particle is associated with an antiparticle, with the same mass but with opposite physical charge (so that electrons are associated with positrons, etc.): an intriguing exemplification of Hegel's view on polarity in nature, as discussed above. Particles and antiparticles annihilate each other, producing photons as a result. Some particles are their own antiparticle, however, and this applies to Majorana fermions of Majorana particles, whose existence was hypothesised by the Italian physicist Ettore Majorana in 1937. Majorana particles became the focus of intense interest because they may serve as building blocks (as stable, error-proof "qubits") for quantum computing. After predicting their existence, Ettore Majorana mysteriously disappeared in 1938. He left a note saying that he made a decision that had become unavoidable. He may have committed suicide, but his body has never been found and it has also been suggested (by novelist Leonardo Sciascia, among others) that, being a devout catholic, he may have decided to become a monk.

So far, Majorana particles remained enigmatic entities, but recently, research groups claimed to have observed "signatures" of these exotic objects (Zhang et al., 2018; Manna et al., 2020). The publication by Zhang et al. in *Nature* was heralded as the "third step" in a Majorana trilogy: from the prediction by Ettore Majorana in 1937, via the group's disappointed first efforts at confirmation, up to the final publication, presented as "definite proof" of the particle's existence.[5] Allegedly, this experiment closed the first chapter in the quest for Majorana particles, and opened the way to the next chapter: working towards quantum information processing based on their unique properties.

Recently, however, the research group involved, led by Leo Kouwenhoven at TU Delft, indicated its growing doubts and concerns as to the validity of their previously published results, while an integrity committee is now investigating whether the research was conducted in accordance with appropriate standards.[6] Obviously, besides scientific prestige, substantial financial interests are at stake, as quantum computing is heralded as the next era in computing. Although no further details were provided, the authors apparently alerted the editors of *Nature* to potential problems in the manner in which the data had been processed, affecting the reliability of the conclusions that had been drawn (Zhang et al., 2020). Ongoing investigations remain confidential until their completion.

This case history concurs with the syllogism of university discourse. S_2 (here represented by a prominent and highly esteemed research group) becomes intrigued (or even obsessed) with an enigmatic entity (the object *a* of particle physics) whose ontological status remains highly uncertain. Majorana research counts as high risk research. It can lead to everlasting fame, but also to disaster. The syllogism can be

[5] https://eurekalert.org/pub_releases/2018-03/duot-mtc032318.php

[6] https://qutech.nl/2020/05/16/expression-of-concern-about-quantized-majorana-conductance-publication/

summarised as follows: a prominent research group (S_2) acquires international fame by announcing a breakthrough concerning research which seems as hazardous as it is inexorable and enticing. The forbidding Majorana particle is an alluring actant, inevitably drawing prominent research groups onto hazardous terrain. Besides academic prestige, enormous financial prospects are beckoning. Thus, the researchers fall victim to their *cupido sciendi*, their will to capture the allusive object (*a*). By giving in to their desire, they become divided subjects ($), caught in the tension between methodological prudence and scientific carefulness on the one hand, and the benefits of priority in research on the other (including the Nobel Prize). This dynamic is captured by the matheme of desire ($ ◇ *a*), where ◇ represents the high-tech contrivances that allow researchers to zoom in on their sub-atomic target, while haste, carelessness or even misconduct are the by-products, the symptoms (emerging in the lower-right position). The first author (Hao Zhang) is now under the suspicion of being a tormented subject who resorted to fraud.

The truth of the constellation is that research, rather than being pure and disinterested, is driven (contaminated) by desire. Ettore Majorana himself was the first victim of the particle he predicted. His breakthrough resulted in an impossible situation, which either resulted in suicide, or in a decision to revert to servitude (S_2 becoming monk, a servant, functioning in service of the Master signifier, the Word of God). In other words, the two version of his death are quite dissimilar. In the case of suicide, his despair ($ in the lower-right position) would have been pushed to the extreme, but in the case of conversion, S_1 would have been elevated ("*aufgehoben*") into the position of the agent, and the quadruped scheme would have taken a clockwise quarter-turn to the right. Ettore would have remained S_2, but now in the upper-right position of the servant, the one who is being called, the one who is addressed.

Bringing the inherent antagonisms and inconsistencies of university discourse to the fore, by questioning its inherent metaphysics for instance, requires a different discourse, however, another anti-clockwise turn of the quadruped scheme, towards the discourse of the analysist, resulting in an oblique perspective on technoscience. Here the focus is on the object of desire (*a*), which is now seen as an actant, initiating the process, becoming an obsession.

Discourse of the Analyst

Although philosophy of technoscience is an academic practice, it entails a change of perspective compared to normal "university discourse" as defined by Lacan. Practicing philosophy of technoscience means adopting an oblique perspective, titling the "normal" stance. Technoscience entails an *intentio recta* as we have seen, addressing the object directly, albeit with the help of technology, enabling us to zoom in on partial objects. Philosophy of technoscience, however, entails an anti-clockwise quarter-turn:

a	$
S_2	S_1

The expertise of the technoscientific expert is suspended (pushed beneath the bar) so that the interaction between the divided subject ($) and the enigmatic object (*a*) comes into full view. Now, the subject is no longer regarded as a (kenotic) qualified technoscientific expert, the cogito of technoscience (S_2), but rather as a tormented subject driven by desire ($): the desire to know (*cupido sciendi*), obsessed by a weird, impossible object, referred to by Lacan as object *a*, something which resists symbolisation (which resists incorporation into the body of accepted knowledge) and whose ontological status is highly precarious, something which cannot be seen or grasped directly: an invisible factor X, a hidden cause, an incarnation of a void, something which may only be visible as a stain or signature on a surface, or as a trace in a cloud chamber, or as a biomolecular entity projected on a computer screen. Psychoanalytically speaking, a technoscientific expert ($) is a pervert, obsessed with a questionable (perhaps even dangerous) entity: say, a tumour in the abdomen of a nude mouse, or the element radium (both toxic and enigmatic), or the gynosome of a "phallic" female Brazilian insect. This obsession is legitimised retroactively, however, in the form of highly-cited research papers, comparable to how the perversion of an artist (say, Baudelaire's vampirism, his biting compulsion) was sanctioned by sublating it into sublime poetry. As technoscience entails the symbolisation or appropriation of the real, however, in the case of technoscience, the product of the interaction between researcher and research object must be something even more symbolic than a poem: a research paper, or a series of publications, or eventually something like a *h*-index (indicating a research program's market value).

CRISPR-Cas9 may serve as an example here. In her autobiography Jennifer Doudna (Doudna & Sternberg, 2017) tells the story of her meeting with Emmanuelle Charpentier in a café in Puerto Rico in 2011, where they decide to coagulate two enigmatic entities, namely CRISPR (DNA sequences in bacteria derived from DNA fragments of viruses that previously infected them) and a mysterious enzyme, a molecular scissor named Csn1 (later rebaptized Cas9) to produce a molecular, high-precision genome-editing machine: a decision which eventually resulted in a "tsunami" of citations. Human agency is questioned in Doudna's autobiography (Zwart, 2019b, p. 69), as CRISPR and Cas9 seemed to have a life of their own, as actants, using hardworking researchers as vectors to coalesce and proliferate.

Evidently, the discourse of the analyst has its deficits as well, such as lack of scientific status (as S_2 is suspended, pushed beneath the bar; Lacan, 1966, p. 794), so that others (S_2) may question whether philosophers are *qualified* to proceed along this path of assessing technoscience. This is the difference between university discourse (where qualified subjects – S_2 – take the floor), and the discourse of the philosopher / analyst, even if the philosopher builds on dialectical experience and established a "track record" for being in science.

Language and the Tormented Subject ($)

Compared to Bachelard, Lacan's focus on "discourse" emphasises the importance of language and the linguistic aspects of technoscience. In order to come to terms with technoscience, we must first and foremost pay due attention to the signifiers used. Language is not an indifferent medium, but always already traversed by antagonisms. Language brutally destabilises our being-in-the-world. Human discourse not only *expresses* psychic turmoil: our entry into the "torture house of language" is itself a traumatic act (Žižek, 2016/2019).

For Lacan (who grew up in a Catholic cultural ambiance) the phrase *In the beginning was the Word* constitutes the starting point for coming to terms with technoscience (Lacan, 1960/1974/2005, p. 89; cf. Lacan, 1960–1961/1991, p. 12). Humans are speaking beings, called upon by language, by the commanding word, the discourse of the Other: the symbolic order which, for humans, is always already there. What is unique about humans is neither their intelligence, nor their convoluted brain, Lacan argues, but first and foremost their openness to language. If I.Q. would be the decisive issue, human intelligence (as the outcome of Darwinian evolution) would have been up to its tasks, allowing us to smoothly adapt ourselves to our environment (cf. 1963/2005, p. 72). But in humans we see a chronic *failure* to adapt, a discord between desire and environment (Chiesa, 2009). It is precisely here, in human discontent, that language intervenes. Language has a disruptive impact on human existence. We are *speaking* animals, liberated from nature, but burdened by language, even sick with language (Lacan, 1960/1974/2005, p. 90, p. 93; Cf. 1961–1962, p. 42).

Due to language, and other dimensions of human culture building on it, notably technoscience, a decisive rupture separates human existence from the natural (pre-symbolic) mammalian world. According to Lacan, without language humans would be happy animals thriving in a natural Umwelt, where visual cues (described by ethologists in terms of *stimulus* and *gestalt*) would unleash pre-established physiological mechanisms (1953/2005, p. 20) as pre-programmed behavioural responses (fight, flight, freeze, arousal, etc.). As animals, humans would dwell in an ambiance of visual gestalt-like stimuli, referred to by Lacan as "the imaginary": basic sets of images, and the repertoire of typical responses triggered by them. But the human world is replete with and disrupted by "the symbolic": norms and expectations, numerical and linguistic information, giving rise to a supra-personal "symbolic order". And it is only because of the symbolic order that technoscience exists: allowing us to come to terms with the Real with the help of a terminological grid of technical terms and other symbolic ingredients (numbers, formulae, measurements, mathematical and chemical symbols, acronyms, equations, computer programs and the like).

For Lacan, technoscientific research entails a process of "symbolisation", transforming geosphere and biosphere with the help of "characters". In ancient Greek, στοιχεῖα (elements) refers to elementary building blocks (of reality or knowledge), but first and foremost to the characters of the alphabet (employed both as letters and as numbers), and this applies to modern technoscience as well. According to Lacan, technoscience is the systematic effort to disclose the basic constituents of nature with the help of symbols: Arabic numbers, alphabetic letters, mathematical symbols, chemical formulae, proliferating acronyms, and so on. These numerical or letter-like (typographical) symbols are the "elements", the symbolic "atoms" by means of which science operates (1960/1974/2005 p. 23, p. 50). Thus, whereas the pre-scientific world of everyday experience continues to rely to a significant extent on images (visible entities, world views, body images, self-images, metaphors, anthropomorphic interpretations, and the like), technoscience develops contrivances (measuring instruments, experimental equipment, etc.) which replace these imaginary, gestalt-like items with standardised terms, numbers, digital data and equations. Molecular genetics, for instance, aims to *see through* the living organism (the visible Gestalt, say: a malaria mosquito) in order to *read* the symbols (the "characters") within: the genotype in the literal sense of "type" (Zwart, 2016). Insofar as science produces images, they are highly technological, such as crystallographic X-ray pictures of DNA: visualised quantifications (Lacan, 1961–1962, p. 42). The symbolisation process gives rise to a terminological grid of signifiers and quantitative numerical data. This means that the technoscientific universe is a radically "inhuman" world (1960/1974/2005, p. 49). Technoscience abstains from anthropomorphism (the tendency to interpret the world from a decidedly *human* viewpoint, p. 50).

Via technoscientific symbolisation, the biosphere is incorporated into the symbolic order as a web of terms, contrivances, machines, networks and the like. Ultimately, the tendency towards symbolisation results in a "literation" (or even *ob*literation) of life (Zwart, 2016). Rather than observing and interacting with (fleshy, messy) *living* beings, molecular biologists prefer to view life as something symbolic: nucleotide code. Although this process may seem to proceed in a smooth and automated manner, it is hampered or disrupted by the recalcitrance of the Real, when symbolisation falters and fails to work (Lacan, 1960/1974/2005, p. 76). The symbolisation or "literation" of the Real gives rise to various by-products in the form of *litter* (including data litter), as technoscience allows humans not only to hominize but also to dramatically *pollute* the world. Think of plastic litter that currently litters not only terrestrial environments but also littoral areas and oceans: plastic packaging, carrying letters – the logos of their producers, left-overs of human λόγος (Zwart, 2015).

Lacan sees humans not as privileged beings (who *have* something which other animals *lack*: big brains, self-consciousness, intelligence, etc.), but as stunted and frustrated subjects, discontent in their socio-technological environment, unable to live up to what is expected of them. Lured and fascinated by the imaginary (erratic longings, erotic phantasies, political utopias, etc.) they are at the same time tormented by norms, commandments and injunctions (e.g. the impossible but highly persuasive injunction of neo-liberal culture to *enjoy* life to the full).

Lacan is especially intrigued by contemporary discontent with technological advances, by human ambivalence triggered by the unstoppable explosion of knowledge production, providing us with a disquieting power over the elementary particles of life and nature (1969–1970/1991, p. 120). While we finally seem able to gratify our desires, we are paralysed by uneasiness and technophobia. In terms of the four discourse, discontent gives rise to the hysteric's discourse:

$	S_1
a	S_2

In this type of discourse, the tormented, discontented subject takes the floor ($) as an agent for whom technoscience is a powerhouse generating questionable top-down authoritative statements (S_1), concerning the safety of GMO food and vaccines for instance, or the necessity of lock-down measures to contain the COVID-19 pandemic. From an oblique perspective, this discourse must be assessed in a symptomatic manner, focussing on its "truth", its object of desire (*a*). What is it these protesters *really* want or fear? What do they mean by *natural* food (versus GMO food), or by *natural* resistance (versus vaccine-induced resistance), for instance? Probably, they see technoscientific items as components of (and as contaminated by) the system which generated the crisis in the first place. Rather than discarding such voices of protest as "irrational", we must look for the kernel of truth (the "moment of truth", as Hegel phrased it). Besides "hysterical" agents ($) and "authoritative" others (S_1), a *product* is involved in this syllogism as well, as technophobia may give rise to new and valid research questions: qualified experts translating societal discontent into "reasonable concerns" (biohazards, health risks, double use, etc.) that can and should be addressed (S_2). From the viewpoint of the tormented subject, however, such translations evidently miss the point. Such mitigating research endeavours cannot compensate the loss of an (imaginary) pastoral world of natural (artisanal) beverages or food items (*a*).

Discontent in technoscience may also arise *inside* the system. One noteworthy symptom, Lacan argues – speaking in 1974, during the heydays of recombinant DNA research, when Nobel Prize laureate Paul Berg published his famous letter in *Science* on "biohazards" of technoscience (Berg et al., 1974) –, is that scientific research itself becomes an "impossible profession" (1960/1974/2005, p. 73; cf. Freud, 1925/1948, 1937/1950). Researchers face a paralysing "crisis of anxiety" (1960/1974/2005, p. 74). While scientists tamper with potentially dangerous bacterial strains in their laboratories, both lay audiences and the experts themselves are alarmed by the idea that these microbes may one day escape from the laboratory, causing pandemics in the outside world (1960/1974/2005, p. 74), perhaps even cleansing the world from human beings; – these unflagging polluters, who caused *le monde* to become *immonde* ("filthy"), as Lacan phrases it (1960/1974/2005, p. 76).

We have now introduced Lacan's four discourses: the discourse of the Master (S_1 as agent), the university (S_2 as agent), the hysteric ($ as agent) and the analyst (the object *a* as agent or actant):

$\frac{S_1}{\$} \rightarrow \frac{S_2}{a}$	$\frac{S_2}{S_1} \rightarrow \frac{a}{\$}$	$\frac{\$}{a} \rightarrow \frac{S_1}{S_2}$	$\frac{a}{S_2} \rightarrow \frac{\$}{S_1}$

In the final two sections of this chapter, I will elucidate the psychoanalytic approach to technoscience by analysing two more case histories: the malaria mosquito and the nude mouse.

Second Case History: Malaria Research

Imagine an international team of life scientists (S_2 as agent) studying malaria mosquitoes. Let us pay due attention to language first of all. The official name for the malaria mosquito, as a particular genus of mosquitoes, is ἀνωφελής, which literally means "useless" (ἀν + ὄφελος), so that the negating prefix "ἀν" already posits the object as a non-object, a refuse. Precisely this allegedly *useless* object, however, may become the focus of choice on which thousands of academics build their careers, so that ἀνωφελής actually provides them, not only with an income, but also with a lifeline into technoscience. Technoscientists may spend years of their lives studying these "useless" entities, hopefully to their benefit, and to the benefit of society as well. What is in a name? A contradiction, for why studying something which is literally useless? A contradiction is a symptom and symptoms make us realise that the focal point of attention is not the mosquito as such, but something "other", something noumenal, something hidden (the object *a*). The mosquito itself merely functions as a cover or carrier for *something else*, namely a parasite officially known as *Plasmodium falciparum*: a dangerous, potentially lethal pathogen, an intruding, disruptive element, the object *a* of malaria research, hiding in the mosquito's intestines, penetrating human skin tissue and transmitted by the bite of a female *anopheles*, causing malaria in humans. Notice that the intentionality of technoscientists is under the sway of negation, because the envisioned outcome of the research is to *eradicate* this parasite (and / or the mosquitoes carrying it, as vectors). The will to decipher (the parasite's secret code) is driven by a will to obliterate and to annihilate. The dialectics of global health requires that a positive result (the eradication of malaria) is the negation of negativity. Remember that life and heath are never a given, but always the outcome of a syllogism (the negation of a disrupting negation, represented by the malaria bug).

Current research focusses on proposals to negate (eradicate) *anopheles* with the help of a CRISPR-Cas9 gene drive system (Scudellari, 2019; Čartolovni, 2017), either by targeting and deleting a particular gene which is vital for female fertility, or by targeting and knocking out the *FREP1* gene, which encodes an immunity protein which helps malaria parasites to survive inside the mosquito's intestines. In other words, we notice a series of displacements (mosquito → intestines → parasite → protein → gene) as successive targets of the death drive of technoscience. A gene drive is basically driven by a death drive, a will to eliminate.

Suppose that the research team mentioned above indeed considers developing a CRISPR/Cas9 -mediated gene to knockout *FREP1* in Anopheles (Dong et al., 2018). This FREP1 gene is not an "object", at least not in the way a mosquito is (as an insect we can see, and whose bite produces a stinging sensation). A gene is not something directly visible or tangible, something we may directly relate to. It is something noumenal. It is a sequence of nucleotides, a piece of DNA, a program containing instructions for protein production. In short, the focus of attention is not the mosquito (the tiny biting female vampire), but a partial object or sur-object, the targeted gene, or a particular DNA sequence belonging to the CRISPR/Cas9 family that will allow researchers to knock out (eliminate) this gene with the help of a molecular scissor. Malaria (a threat to human health, a challenging *negation*) is to be eliminated with the help of a knock-out device (the negation of this negation) to safeguard the immunity of the human species.

Gene drive exemplifies the inherent *negativity* of technoscience. A gene drive is a *disruptive* technology, intentionally disrupting key genes essential for female fertility in mosquitoes, so as to *eradicate* disease vector populations. "Selfish" genetic elements are consciously exploited to spread a genetic modification from laboratory mosquitoes to field populations (Windbichler et al., 2011) and to confer a "negative fitness effect" on the target population (Hammond et al., 2017). Notice that "negative fitness" is a dialectical term, indicating that molecular life sciences research is *inherently dialectical*, it is the negation of a negation (targeting a parasite who is targeting us). Gene drives are self-perpetuating, however. They spread by themselves and, once implemented, continue to radiate through the target population (Scudellari, 2019; Collins et al., 2017). They are resistance proof (Kyrou et al. 2018) and there is either no evidence for the occurrence of resistant mutations, or the likelihood of occurrence can be intentionally reduced (Hammond et al., 2017). The big issue is not whether gene drives work, but how to control, contain and reverse them, how to disrupt the disruptor, the killer machine, if necessary? Again: how to negate the negation?

There is evidently a hint of perversity at work in studying vampire mosquitoes and lethal pathogens dwelling in their intestines. As Lacan indicates, there is a structural concordance between university discourse and perversity, namely the obsession with a partial object, dangerous and enigmatic, extraordinary and valuable (referred to by Lacan as object *a*). The product of the process will be a series of publications: papers in academic journals (probably containing glossy images of pathogens and DNA sequences). These products can be considered as "sublimation", a symbolic sublation and justification of the researcher's questionable desire. In addition, although biomolecular research as such will focus on targeted non-objects or sur-objects (e.g. a gene, a strain of nucleotides, etc.), other issues are involved as well, such as biosafety considerations. When working with potentially dangerous organisms, how to prevent dangerous pathogens from leaking into the outside world, or how to prevent pathogen theft? Also, environmental considerations are evidently at stake: what will be the ecological collateral damage of eradicating anopheles, this allegedly *useless* mosquito? And finally, how to prevent a unilateral flow of (patentable, valuable) knowledge from sub-Saharan Africa to research institutes in the global North? For indeed, while ἀνωφελής means useless, or even "unprofitable" (ὄφελος may also mean *benefit* or *profit* in Greek), the knowledge procured and extracted from researching these mosquitoes may become a valuable commodity (may be sublated into patentable knowledge and similar ownable products, appropriated by the global technoscientific enterprise).

In short, in malaria research, a plethora of philosophical niceties are involved, from dialectical ontology up to the normative dimensions of global biodiversity, ownership (accessibility) of knowledge and intellectual property rights. These additional challenges may give rise to the development of additional (complementary) forms of expertise, such as environmental science or bioethics – e.g. genres of expertise concerning risk prevention and benefit sharing: how to share the financial benefits derived from researching "unprofitable" mosquitoes? These specific forms of auxiliary expertise display a tendency to revert to the syllogism of university discourse as well: the ethicist operating as a qualified expert (S_2), whose expertise should not impose a barrier to technoscience, nor limit its progress, but merely help to establish the best results for an equal and inclusive society (Neves & Druml, 2017). A form of expertise in short which, in the discourse of the analyst, becomes suspended.

The oblique perspective adopted by continental philosophy of technoscience concurs with what Lacan refers to as the discourse of the analyst:

a	*$*
S_2	S_1

In this type of discourse, the focus is on questioning (zooming in on) the symptomatic intricacies emerging in the interaction (above the bar) between the craving subject's will to know (*cupido sciendi*) and an enigmatic agent. This interaction is represented here by the tormented expert (*$*), driven into action by the elusive, dangerous object, now acting as agent or actant (*a*). The focus is on the disparities of the situation, e.g. on explaining how an insect (formally known as unprofitable) becomes a source of value, triggering a plethora of research initiatives. The epithet ἀνωφελής is symptomatic of the dialectical disparities involved. Moreover, also in this case there is an (unintended) product or by-product involved, as indicated by the scheme, namely something normative (S_1 in the lower-left position). Eventually, philosophical involvement may result in a normative "product", e.g. a series of normative (bioethical) guidelines for safeguarding research integrity and implementing policies of benefit sharing. A normative outcome or product is what philosophers are eventually expected to produce: a series of normative principles or guidelines (S_1), so that "normal" university discourse may be re-established (via a clock-wise quarter turn of the scheme) and safeguarded from disruption. This normative outcome (in the form of ethical guidelines) replaces the imperatives of the Master, pushed beneath the bar in university discourse. Whilst emancipated (Enlightened) technoscience is still in need of legitimising directives, these are no longer provided apodictically (*ex cathedra*), but in a format qualified technoscientific experts can (be trained to) work with, e.g. guidelines established by qualified normative (bioethical) experts, operating in accordance with the logic of university discourse.

This means that philosophers of technoscience themselves will be facing a chronic disparity as soon as they become involved in this type of research (Zwart, 2018a). While the philosophers themselves may prefer to study the dialectics of power and desire at work in actual research practices from an oblique perspective (thereby opting for the "discourse of the analyst"), they are eventually expected to come up with normative tools that legitimise their involvement (which would require a clock-wise turn, towards "university discourse"). Such normative tools (as products of their analyses) would allow researchers, research managers and funding organisation to address potential disruptions. Technoscience is an "administered world" where normative challenges must be addressed through ethical engineering. Technoscience seems in need of ethical expertise, rather than excessive problematisation and interminable questioning. This is an inherent antagonism or contradiction at work in the discourse of the analyst, which may result in a regression, when philosophers shy away from "interminable analysis" and revert to the position of qualified bioethical experts (exchanging an oblique perspective for validated expertise, and the discourse of the analyst for university discourse, a change of roles which requires a clock-wise quarter-turn of the quadruped scheme to the right).

Lacan's theorem of the four discourses is sometimes regarded as a device which operates in a more or less mechanical manner and therefore subjected to the same kind of criticism also directed at Hegel, whose dialectical schema's (A, B, E, etc.) may likewise suggest a mechanical practice of applying triadic formulae, so that every antagonism inevitably radicalises into extremity and thereby becomes resolved, and so forth. What is obfuscated in such a mechanistic misunderstanding is that what we are dealing with are hazardous and disconcerting processes. As Žižek (2016/2019) phrases it, in dialectical processes, there is no "normal progress". Dialectical processes involve obstacles, inhibitions, impediments, inertia, fixations, repetition and the like. Why do we pass from one position to the next? Why do we move from the discourse of the analyst to university discourse and back? This does not happen "automatically". Things become disrupted because of the experience of getting stuck. Dialectical experience is first of all the experience that something is *not* working. As an example, Žižek mentions Hegel's comments on phrenology, i.e. the conviction that the mind is a bone, i.e. that the characteristics of the human psyche are conditioned by the shape of the skull. A similar idea is present in the claim that human existence is essentially conditioned by the genome. Such objectifications prove a dead-end. On closer inspection, *nothing* is explained by such a claim, so that, eventually, even stringent partisans are forced to mitigate their views and to allow other factors to "compromise" their truth. Eventually, research becomes impeded by the weight of such claims (p. 77), while otherness reappears precisely in that which the claim initially excluded ("nurture" instead of "nature", etc.). This also applies to Lacan's discourses. Like the dialectics of master and servant, the shift from a Master's discourse to university discourse, and subsequently from university discourse to the discourse of the analyst, is an intricate and hazardous process, not at all a mechanical routine.

Third Case History: The Nude Mouse

As indicated, the body of organisms operates as an immunisation device safeguarding the integrity of individuals. On closer inspection, immunity is a phenomenon which requires thorough dialectical rethinking (Gilbert & Tauber, 2016). Biology, these authors argue, is a "dialectical discipline", and living nature a "dialectical world" (p. 842). The initial view sees individuals as insulated organisms (M_1), threatened with negation by a hostile environment, teaming with pathogenic microbes from which they must be protected (M_2). This antagonistic, defensive view, Gilbert and Tauber convincingly argue, must be displaced by a more comprehensive, dialectical approach which sees organisms as "holobionts", as consortia of hundreds of symbiotic species, e.g. host organisms and their microbiomes. As a result, immunity is not a purely defensive mechanism (M_2), but the net balance between rejection and assimilation. Thus, the one-sided, defensive view gives way to a dynamical interaction between organism and ecosystem (M_3). This dialectic of immunity is given an additional dialectical turn in the case of laboratory animals, whose immune system is challenged for the purpose of research.

Wild type animals are recalcitrant objects, and therefore not the ideal (kenotic, transparent) targets of research, as this requires optimal plasticity and modifiability. Even in malaria mosquitoes, potential resistance to disruptive interventions remains an issue of concern. Inside the laboratory, we aim to penetrate nature and to exploring the "things in themselves", with the help of research objects of choice, exemplified by a particular category of objects known as "model organisms". Their ontological status is fluid, hovering in the boundary zone between the artificial and the natural. They actually may be seen as representing an ontological category of their own, halfway between living beings and laboratory gadgets, trans-animals as it were.

Initially (M_1), we encounter the recalcitrance of life in the form of an epistemological obstacle: the resistance of living beings, whose bodies act as immunisation devices. This is the first moment, the first experience of "getting stuck": the undeniable nastiness of working with animal models, whose bodies are *really alive*, sensitive and irritable, so that research ambitions may be seriously impeded. To overcome resistance of the real, an element of sadism seems to be at work in animal research (M_2): the laboratory as a torture house, confirming the syllogistic congruence between university discourse and the position of the pervert.

Then, however, something unexpected happens. A laboratory artefact is produced by accident, a nude mouse, discovered in 1962. The nude mouse is by now a standard laboratory-dweller: a strain of mice with a genetic mutation resulting in the absence of a thymus and an inhibited immune system (due to a significantly reduced number of T cells). The nude mouse can therefore receive many different types of tissues, tumours and grafts, without mounting a rejection response. This is the technoscientific ideal of the natural: a system without opacity, without resistance. The nude mouse is a unique model for experimentally producing, imaging and treating tumours. The nude mouse embodies the second moment of the process, under the sway of negativity (M_2), but now in a purified version. The nude mouse pushes the concept of a model organism to its extreme. Its ontology is characterised by *absence* (absence of a thymus, absence of an immune system, absence of hair).

The genetic basis for the nude mouse (as the phenotype) is a mutation: a disruption of the FOXN1 gene (the genotype), which occurred by accident, but was immediately exploited. The most striking outward appearance is the absence of fur. Because of a monogenetic defect (in the FOXN1 gene) the nude mouse suffers from a number of deficits which, in the context of a laboratory (as a world *in reverse*), actually constitute a benefit. Normally, research with animals is under the sway of the dialectic of action and reaction, so that intrusion unleashes resistance, a dialectic which gave rise to the discovery of "irritability" by Albrecht von Haller and others already in the eighteenth century. And indeed, disruption and irritability are important components of the syllogism of animal research. The epistemology of disruption either functions *per via de levare*, by removing or disconnecting organs, one after the other (Zwart, 2015), or *per via di porre*, by adding something (a carcinoma, a tumorous growth), but the irritable animal's body offers resistance against such intrusions.

Irritability basically means that animals can suffer. Technoscientific research demonstrates that the *integrity* of the body is more than merely or normative principle, more than a mere "idea". Rather, it is a *dialectical* idea (in the Hegelian sense): an idea which *realises itself*, in the form of resistance or rejection, as the actualisation of the principle of integrity. Integrity as a *general* principle (A) is challenged by *particular* intrusions (in the context of an experiment: B), giving rise to a *concrete* response (e.g. rejection of the allograph: E). In the case of a nude mouse, however, the body responds with *indifference* to intrusions, so that the natural syllogism becomes disrupted ($A \rightarrow B \mid \rightarrow E$). The athymic, hairless (nude) mouse becomes a kenotic object, a living test-tube, a receptacle, perfectly modifiable, open to the negativity of technoscience.

Because of its inhibited immune system, the nude mouse becomes the ideal recipient of allografts and xenografts: obnoxious implants coming from other individuals or species: *extimate* intrusions, symbolising intimate disruptive otherness (Zwart, 2017; Aydin, 2021). The nude body displays a dramatic inability to eliminate the intrusion, but from the point of view of negativity, this deficit is actually a benefit (as two negatives yield a positive). The intrusive, extimate allo- or xenograft becomes the objects *a* of technoscience: a cancerous growth, a disruptive stain, something which can be meticulously monitored and quantified, the target of pictures and curves which can be incorporated in journal papers, while the mice themselves, after having reached their "humane end-point" – i.e. the condition when physiological or behavioural signs indicate that an experimental animal has attained the agreed maximum of pain or distress – are euthanised via a procedure known as cervical dislocation.

The nude mouse became a successful species, both commercially and researchwise (Rader, 2004). Nude mice are arguably the most widely used mammalian models in biomedical research, especially in oncology and immunology. A hairless creature whose immune system is compromised is sublated into something valuable and positive (the negation of the negation). The nude mouse becomes especially beneficial for humans (for us, *naked apes*) because nude mice represent perfect models for studying illness in humans. Something negative, e.g. a cancerous tumour, inserted into the body, in the form of an allograft, becomes a highly valuable excess, the object *a* of biomedical research: the embodiment of something which should not be there, and is nonetheless meticulously monitored with care. The thing in itself is opened up, the body becomes transparent and the biomolecular dynamics of cancer can be studied. The divide between subject and object, phenomenon and noumenon is lifted.

Antagonisms and contradictions persist, however, notably coming from the super-ego of technoscience. On the one hand, the imperative is: continue to produce more data, in support of the "war on Cancer"! On the other hand, conflicts of conscience may arise, because of the inevitable nastiness of the handiwork of technoscience, framed as "necessary evil" (Pijnappel, 2016). Somehow, a contribution will be made, teleologically speaking (some progress in the interminable fight against cancer), but the chance that *this particular* experimental trial will have a beneficial result, remains infinitesimally small. The research effort will result in things like *papers*, *citations* and *additional research grants*, but cancer will not be eradicated. Rather, the War on Cancer proves an interminable affair. As Ellen ter Gast (2007) convincingly argued, should progress be made at all, nude mice rather than technoscientific research managers should be awarded the Nobel Prize.

References

Aydin, C. (2021). *Extimate technology: Self-formation in a technological world*. Routledge.

Bachelard, G. (1933/1975). *Les intuitions atomistiques: essai de classification*. Vrin.

Bachelard, G. (1934/1973). *Le nouvel esprit scientifique*. Presses Universitaires de France.

Bachelard, G. (1938/1949). *La psychanalyse du feu*. Gallimard.

Bachelard, G. (1938/1970). *La Formation de l'esprit scientifique: Contribution à une psychanalyse de la connaissance objective*. Vrin.

Bachelard, G. (1940/1949). *La Philosophie du non. Essai d'une philosophie du nouvel esprit scientifique*. Presses Universitaires de France.

Bachelard, G. (1948). *La terre et les rêveries de la volonté*. Corti.

Bachelard, G. (1949/1962). *Le rationalisme appliqué*. Presses Universitaires de France.

Bachelard, G. (1951). *L'activité rationaliste de la physique contemporaine*. Presses Universitaires de France.

Bachelard, G. (1953). *Le matérialisme rationnel*. Presses Universitaires de France.

Berg, P., et al. (1974). Potential biohazards of recombinant DNA molecules. *Science, 185*, 303.

Čartolovni, A. (2017). Teilhard de Chardin's oeuvre within an ongoing discussion of a gene drive release for public health reasons. *Life Sciences, Society and Policy, 13*, 18. https://doi.org/10.1186/s40504-017-0064-8

Chiesa, L. (2009). The world of desire: Lacan between evolutionary biology and psychoanalytic theory. *Filozofski vestnik, 30*(2), 83–112.

Collins, J., Emerson, C., Heitman, E., & Oye, K. (2017). Debating the ethics of gene drives. *Pathogens and global health, 111*(8), 404–411.

Dong, Y., Simões, M. L., Marois, E., & Dimopoulos, G. (2018). CRISPR/Cas9 -mediated gene knockout of Anopheles gambiae FREP1 suppresses malaria parasite infection. *PLoS Pathogens, 14*(3), e1006898. https://doi.org/10.1371/journal.ppat.1006898

Doudna, J., & Sternberg, S. (2017). *A crack in creation: Gene editing and the unthinkable power to control evolution*. Houghton Mifflin Harcourt.

Eyers, T. (2012). Bachelard, Lacan and the impurity of scientific formalization. *Paragraph, 35*(3), 320–337.

Foucault, M. (1994). Qu'est-ce qu'un auteur. In *Dits et Écrits* (pp. 789–809). Gallimard.

Freud, S. (1920/1940). Jenseits des Lustprinzips. In *Gesammelte Werke XIII* (pp. 1–70). Imago.

Freud, S. (1925/1948). Geleitwort zu *Verwahrloste Jugend* von August Aichhorn. In *Gesammelte Werke XIV* (pp. 565–567). Imago.

Freud, S. (1930/1948). Das Unbehagen in der Kultur. In *Gesammelte Werke XIV* (pp. 419–513). Imago.

Freud, S. (1937/1950). Die endliche und die unendliche Analyse. In *Gesammelte Werke XVI* (pp. 59–99). Imago.

Freud, S. (1950). *Aus den Anfängen der Psychoanalyse. Briefe an Wilhelm Fliess, Abhandlungen und Notizen aus den Jahren 18871902*. Imago.

Gay, P. (1988). *Freud: A life for our time*. Dent.

Hammond, A. M., Kyrou, K., Bruttini, M., North, A., Galizi, R., Karlsson, X., et al. (2017). The creation and selection of mutations resistant to a gene drive over multiple generations in the malaria mosquito. *PLoS Genetics, 13*(10), e1007039. https://doi.org/10.1371/journal.pgen.1007039

Gilbert, S., & Tauber, A. (2016). Rethinking individuality: The dialectics of the Holobiont. *Biology and Philosophy, 31*(6), 839–853. https://doi.org/10.1007/s10539-016-9541-3

Gilead, A. (2020). A comment about the meaning and significance of life in the light of generalized crystallography. *Foundations of Chemistry*. https://doi.org/10.1007/s10698-020-09367-3

Haraway, D. (2008). *When species meet*. University of Minnesota Press.

Kyrou, K., Crisanti, A., et al. (2018). A CRISPR–Cas9 gene drive targeting *doublesex* causes complete population suppression in caged *Anopheles gambiae* mosquitoes. *Nature Biotechnology, 36*, 1062–1066.

Lacan, J. (1938/2001). Les complexes familiaux dans la formation de l'individu: Essai d'analyse d'une fonction en psychologie. In *Autres Écrits* (pp. 23–84). Éditions du Seuil.

Lacan J. 1953/2005. Le symbolique, l'imaginaire et le réel. In: Lacan J. (2005) *Des Noms-du-Père* (pp. 9–63). Paris: Éditions du Seuil.

Lacan J. (1960–1961/1991). *Le Séminaire VIII: Le Transfert*. Éditions du Seuil.

Lacan, J. (1954–1955/1978). *Le séminaire II: Le moi dans la théorie de Freud et dans la technique de la psychanalyse*. Éditions du Seuil.

Lacan, J. (1957–1958/1998). *Le séminaire V: Les Formations de l'inconscient*. Éditions du Seuil.

Lacan, J. (1960/1974/2005). *Discours aux Catholiques/Le triomphe de la religion*. Éditions du Seuil.

Lacan, J. (1961–1962). *Le Séminaire IX: L'identification*. http://staferla.free.fr/

Lacan, J. (1962–1963/2004). *Le Séminaire Livre X: L'Angoisse*. Éditions du Seuil.

Lacan, J. (1963/2005). Introduction aux noms-du-Père. In *Des Noms-du-Père* (pp. 65–104). Éditions du Seuil.

Lacan, J. (1964/1973). *Le Séminaire XI: Les quatre concepts fondamentaux de la psychanalyse*. Éditions du Seuil.

Lacan, J. (1966). *Écrits*. Éditions du Seuil.

Lacan, J. (1969–1970/1991). *Le séminaire XVII: L'envers de la psychanalyse.* Éditions du Seuil.

Lacan, J. (1975–1976/2005). *Le séminaire XXIII: Le sinthome*. Éditions du Seuil.

Lenin V. I. (1921/1965). Concerning the conditions ensuring the research work of academician I. In P. Pavlov and his associates. *Collected works XXXII*. Progress.

Manna, S., et al. (2020). Signature of a pair of Majorana zero modes in superconducting gold surface states. *PNAS, 117*(16), 8775–8782. https://doi.org/10.1073/pnas.1919753117

Marx, K. (1867/1979). *Das Kapital: Kritik der politischen Ökonomie I*. Dietz Verlag.
Nietzsche, F. 1980. Morgenröte. Sämtliche Werke. Kritische Studienausgabe, Hrsg. G. Colli, M. Montinari. DTV/De Gruijter.
Pannekoek, A. (1951/1961). *A history of astronomy*. Allen & Unwin.
Pijnappel, M. (2016). *Lost in technification: Uncovering the latent clash of societal values in Dutch public policy discourse on animal-testing alternatives*. RUN.
Patrão Neves, M., & Druml, C. (2017). Ethical implications of fighting malaria with CRISPR/Cas9. *BMJ Global Health, 2*, e000396. https://doi.org/10.1136/bmjgh-2017-000396
Rader, K. (2004). *Making mice: standardizing animals for American biomedical research (1900–955)*. Princeton/Chicago: Princeton University Press.
Roudinesco, E. (1986). *La bataille de cent ans. Histoire de la psychanalyse en France 2 (1925-1985)*. Éditions du Seuil.
Scudellari, M. (2019). Self-destructing mosquitoes: The promise of gene drives. *Nature, 571*, 160–162. https://doi.org/10.1038/d41586-019-02087-5
Sokal, A., & Bricmont, J. (1998). *Intellectual impostures/fashionable nonsense: Postmodern intellectuals' abuse of science*. Picador.
Ter Gast, E. (2007). *Biotech pioneers, a philosophical inquiry concerning the genetically engineered mouse*. RTODTO/RUN.
Todes, D. P. (2002). *Pavlov's physiology factory: Experiment, interpretation, laboratory enterprise*. John Hopkins University Press.
Todes, D. P. (2014). *Ivan Pavlov: A Russian life in science*. Oxford Unversity Press.
Windbichler, N., Crisanti, A., et al. (2011). A synthetic homing endonuclease-based gene drive system in the human malaria mosquito. *Nature, 473*, 212–215.
Zhang, H., et al. (2018). Quantized Majorana conductance. *Nature, 556*, 74–79. https://doi.org/10.1038/nature26142
Zhang, H., Liu, C. X., Gazibegovic, S., et al. (2020). Expression of concern: Quantized Majorana conductance. *Nature, 581*(7870), E4. https://doi.org/10.1038/s41586-020-2252-6
Žižek, S. (2016/2019). *Disparities*. Bloomsbury.
Zwart, H. (1995). Ik ben een machine... Over het Cartesiaanse gehalte van de Freudiaanse Zelfconceptie. In: H. Hermans (red.) *De echo van het ego: over het meerstemmige zelf*. Annalen van het Thijmgenootschap, 83 (2) (pp. 49–80). Ambo.
Zwart, H. (2001). *De wetenschapper als auteur. Geschiedenis en toekomst van het wetenschappelijk communiceren (oratie)*. Sun.
Zwart, H. (2010). The Nobel Prize as a reward mechanism in the genomics era: Anonymous researchers, visible managers and the ethics of excellence. *Journal of Bioethical Inquiry, 7*, 299–312.
Zwart, H. (2014). The elephant, the mirror and the ark: Rereading Lacan's animal philosophy in an era of ontological violence and mass extinction. *Journal of Critical Animal Studies, 12*(1), 1–32.
Zwart, H. (2015). Tainted food and the Icarus complex: Psychoanalysing consumer discontent from oyster middens to Oryx and crake. *Journal of Agricultural & Environmental Ethics, 28*, 255–275. https://doi.org/10.1007/s10806-015-9530-6
Zwart, H. (2016). The obliteration of life: Depersonalisation and disembodiment in the terabyte age. *New Genetics and Society, 35*(1), 69–89. https://doi.org/10.1080/14636778.2016.1143770
Zwart, H. (2017). 'Extimate' technologies and techno-cultural discontent: A Lacanian analysis of pervasive gadgets. *Techné: Research in Philosophy and Technology, 21*(1), 24–54. https://doi.org/10.5840/techne20174560
Zwart, H. (2018a). Method of avoidance or exercise in retrieval? A Lacanian assessment of bioethics discourse. *Ethical Perspectives*, 753–793.
Zwart, H. (2018b). Conditioned reflexes and the symbolic order: A Lacanian assessment of Ivan Pavlov's experimental practice. *Vestigia: The Journal of the International Network of Psychotherapeutic Practice, 1*(2), 58–95.

Zwart, H. (2019a). *Psychoanalysis of technoscience: Symbolisation and imagination*. Series: Philosophy and psychology in dialogue 1. LIT Verlag. ISBN 978-3-643-91050-9.

Zwart, H. (2019b). Enter CRISPR: Jennifer Doudna's autobiographical assessment of the science and ethics of CRISPR/Cas9. *Ethics in Biology, Engineering and Medicine: An International Journal, 9*(1), 59–76. https://doi.org/10.1615/EthicsBiologyEngMed.2019030275

Zwart, H. (2020a). Iconoclasm and imagination: Gaston Bachelard's philosophy of technoscience. *Human Studies, 43*, 61–87. https://doi.org/10.1007/s10746-019-09529-z

Zwart, H. (2020b). *Styles of thinking*. Series: Philosophy and psychology in dialogue 2. LIT Verlag. ISBN 978-3-643-96300-0.

Chapter 5
Louis Althusser: Science and Ideology

Rereading Marx

In terms of design and key objectives, this volume entails a triadic syllogism. Continental thinking constitutes its source material, and first of all I offer a concise exposition of the way in which Hegel, Marx, Engels, Bachelard, Lacan and Heidegger allow us to come to terms with technoscience. As indicated, notwithstanding multiple differences and interventions, I see their oeuvres as building on a common ground. I also acknowledge the second moment (the negation), however, consisting of claims (brought forward by various authors) that this corpus of literature, or parts of it, are invalid or outdated, for instance because the future belongs to neo-liberalism (as Francis Fukuyama argued), or because continental thinking is flawed by Eurocentric and androcentric biases. Rather than countering or criticising this type of criticism directly and extensively (which would result in more or less "theoretical" debates), I have adopted a more "cataphatic" course. By outlining its basic logic (its methodology) and by extrapolating it to a number of case studies, my aim is to demonstrate the viability, urgency and contemporary relevance of a continental approach ("via positiva").

This chapter is different, however, in the sense that an exception is made for Louis Althusser. His work may be seen as an obstacle blocking the way, and obstacle "from within" moreover, notably his claim that the approach which is presented as a unity here, is actually dirempted by an epistemological rupture, between Hegel ("ideology") and Marx ("science"), although according to Althusser the early Marx still errs on the Hegelian side of the divide. The criticism of Engels discussed in Chap. 3 was likewise an attempt to create a divide between science and ideology, in this case, between Marx and Engels. In order for my exercise in retrieval to be convincing, these "obstacles" from within must be duly addressed, also because of their impact on more recent debates, not by eliminating them, but by thoroughly considering it and sublating them.

H. Zwart, *Continental Philosophy of Technoscience*, Philosophy of Engineering and Technology 38, https://doi.org/10.1007/978-3-030-84570-4_5

In Chap. 3 we already indicated how, according to Louis Althusser (1918–1990), Karl Marx founded a new science with a methodology and problematic of its own, so that his role in history is comparable to that of Galileo in physics and Lavoisier in chemistry. Absorbed in his scientific activities, however, Marx never managed to produce a dialectic of his own, Althusser contends. He never found or took the time to write a Marxist version of Hegel's *Logic*, although the outlines of a Marxist philosophical method are nonetheless available. They can notably be found in the prefaces and epilogues accompanying his major scientific publications, such as *Contribution to the Critique of Political Economy* (published in 1859) and *Capital, Volume I* (published in 1867). In order to bring the *specificity* of the Marxist dialectic (compared to the Hegelian model) to the fore, Althusser adopts a quite remarkable reading method, positing a rupture, not only between the younger ("ideological") and the later ("scientific") Marx, but also between Hegel and Marx (although the formidable spectre of the former continued to haunt the writings of the latter, both implicitly and explicitly).[1] This reading method actually entails a series of apodictic *interventions*, contradicting (or at least challenging) literal statements made by Marx and Engels themselves concerning their relationship with Hegel. More precisely, the idea of a rupture reflects Althusser's effort to reread Marx from a Spinozist perspective. Although Althusser (1964) claimed that the birth of Marxism was an unexpected event (in the absence of a legal father), what he actually tried to do was to replace Hegel (as Marx's intellectual father figure) by Spinoza. In other words, he drastically adapted the actual (historical) intellectual genealogy by disconnecting Marx from Hegel and reconnecting him with Spinoza. In terms of the logic of chemism, Althusser saw a stronger intellectual "affinity" with the latter.

Rather than being a contribution to "Althusser studies", this chapter focuses on the impact of Althusser's remarkable move for developing a dialectics of contemporary technoscience. Although Althusser's endeavour (his effort to systematically eradicate the Hegelian legacy from Marx's oeuvre) inevitably results in a series of contradictions, of a questionable and inhibitory nature as I will argue, on closer inspection some of his results may nonetheless contribute to, and become incorporated into, the development of a philosophical dialectic: an exemplification of the cunning of reason, if you like. As indicated, my aim is to sublate, rather than eliminate his arguments.

The syllogism elaborated in this chapter consists in a number of steps. First of all, as was already pointed out, we must keep in mind that, while Marx produced an immense body of literature (part of which was co-authored with Engels, and only part of which was published during his lifetime), Althusser limits himself (filters his reading) to a relatively small set of documents, as if to protect himself against overstimulation. Indeed, one inevitably gets the impression that Althusser carefully selected and analysed a containable sample of discursive input for his project. It was never his intention to conduct a "scholarly (i.e. "literal" and comprehensive)

[1] This chapter focusses on Althusser's influential publications from the 1960s. According to Agon Hamza (2016, p. 138), later in life Althusser became critical of his concept of the *epistemological break* and even came to admit that Marx did not break away from Hegel.

reading of Marx. Rather, his aim was to restore Marx's work to clarity, as he phrased it, seeing Marx's own writings as raw materials as it were. In his autobiography, Althusser (1985/1992) explains, moreover, that his philosophical method did not involve reading philosophical texts or oeuvres in their entirety. Rather, he would "drill" or "bore" into them, so as to draw a "soil sample" from the "discursive formation" at hand, from which to intuit the whole. Even when reading such core samples, moreover, Althusser tends to read them quite selectively, as we will see, with a strategic objective in mind. For Althusser, philosophy is *intervention*, and this already applies to the reading process, which can be characterised as a *transformative* reading practice.

As these key methodological documents written by Marx were already briefly discussed in Chap. 3, the focus will now shift to Althusser's reading of them, highlighting the tension between his initial (still rather dialectical) reading during the 1950s and the more radical ("Spinozist") style of reading adopted during the 1960s, resulting in *Pour Marx* ("For Marx", 1965/1974) and *Lire le Capital* ("Reading Capital", 1965/1968). As indicated, the relationship between Hegelian and Marxist dialectics (continuity or difference?) is the core problematic of Althusser's writings. Initially, Althusser sees Marxism as a scientific and materialistic version of Hegelianism, in line with how Marx and Engels themselves envision their own work. This is the position adopted in *On Marxism* (1953/1997), where Althusser stays relatively close to the literal self-positioning by Marx and Engels. During the 1960s, however, Althusser claims that an insurmountable *rupture* separates Hegelian dialectics ("ideology") from Marxist dialectics ("science"). In accordance with the spirit of the sixties, moreover, this claim tends to radicalise in the course of his writings. Althusser discards the authority of Hegel, who is replaced by other (more radical) authorities, such Spinoza and Mao Zedong. Although Marx and Engels themselves consistently retained their connection with Hegel, Althusser argues that we are now in a position to develop a more rigorous understanding of the *specificity* of Marxism as a science.

Subsequently, Althusser's reading will be critically assessed. I will point out how his interventions inevitably result in a series of contradictions (or even cul-de-sacs) which can only be addressed convincingly if reconsidered from a dialectical perspective. Special attention will be given to two of Althusser's interventions, namely his segregation between the "object of knowledge" and the "real object", and his interpretation of Engels' comparison between Marx and Lavoisier. Finally, my critical assessment will be put to the test by reading *Philosophie et Philosophie Spontanée des Savants* ("philosophy and the spontaneous philosophy of the scientists"), published by 1967, a text in which Althusser explicitly discusses contemporary life sciences research (biochemistry and evolution).

Practising Dialectics: Active Reading (First Moment)

In an early text on Marxism, entitled *On Marxism* (1953/1997), Althusser explains how Marxism is both a science and a practice. It is a science which is tested, verified and developed *in practice*, a science which both studies *and* practically addresses the contradictions arising in social reality. And while historical materialism is the scientific study of the development of social formations, dialectical materialism is Marxist philosophy (the Marxist dialectic). Dialectics is not something which emerges spontaneously, moreover. Precisely because it is a science, it must be consciously developed and taught. It inspires practical political activity, but also seeks verification through practice. Whereas Marx and Engels continued to use dialectical concepts adopted from Hegel (such as "interaction", "contradiction" and "qualitative leaps") their practice is nonetheless different, because they study society as a real material process rather than as an expression of ideas. According to Hegel, the development of ideas determines the development of the real world (in conformity with the triadic dialectical laws), but Marx and Engels opt for a reversal: the real world now constitutes the starting point. Hegelian dialectics is an "anticipation" of Marxist dialectics as a scientific method, but the latter entails a drastic modification of dialectical laws, making them more precise and consonant with a scientific approach.

Dialectics studies contradictions, both in human history and in nature, as especially Engels emphasised, Althusser contends. This also implies that Marxism embraces materialism, not as a metaphysical position (an ideology), but as a scientific practice which emphasises the primacy of existence over consciousness, and of external reality over ideas. Matter is primary, consciousness is secondary. To see human consciousness as primary is a bourgeois point of view.

Besides Marx and Engels, Althusser also builds on texts by Lenin, notably *Materialism and Empiriocriticism* and the *Philosophical Notebooks*, which include his "Conspectus" of Hegel's *Science of Logic* and of his *Lectures on the History of Philosophy* (Lenin, 1976). Lenin likewise argues that materialism is a practice verified by science. Materialism is a *scientific* philosophical position: a rejection and radical criticism of idealism, a critique of bourgeois philosophy (which sees the thinking subject as the demiurge of a fictitious subjective pseudo-world). While Marxism studies actuality (the actual world), bourgeois idealism amounts to intellectual "onanism". From a dialectical materialist perspective, atoms and electrons are not only moments in the concrete development of a science, but also aspects of material reality. Technoscience is materialistic also in the sense that it actively *transforms* the world. In contrast to bourgeois idealism, technoscience consciously generates material change. Dialectical materialism is informed by the results and experiences of scientific research, but provides methodological guidance to research as well.

In short, Althusser's essay *On Marxism* concurs with the dialectical position that was adopted by Marx and Engels. It is the first moment if you like (M_1) in Althusser's reading of Marx. Compared to this initial position, his writings during the 1960s present a moment of negation: of rupture and separation (M_2). Now, his aim is to emphasise the *specificity* of Marxism as rigorously as possible, notably by invoking an (allegedly insurmountable) rupture between Hegelian ideology and Marxist science. In the course of the 1960s, Althusser's position radicalises into an overtly anti-Hegelian stance.

Symptomatic Reading (the Second Moment)

In *On the Young Marx* (1961/2005), Althusser's verdict is still relatively mild. For Marx as a young bourgeois intellectual, Althusser argues, Hegel was not the "library Hegel", but the Hegel of the neo-Hegelian movement: present as a hovering spectre. Yet, although Marx was "haunted" by the long shadow (the "spectre") of Hegel, at a certain point he managed to liberate himself from this legacy, *passing* over into materialism, thereby radically changing the "problematic" of his work. In other words, Marxism as a science is the result of a rupture, an intellectual mutation. Marx now becomes active in a completely different field, addressing a completely different spectrum of questions than Hegel did. The problematic of his oeuvre is not immediately manifest, however, but must be actively brought to the surface, via a process of "symptomatic reading", even if this means contradicting the author's own statements and proclamations. Thus, even if Marx proclaims himself a scholar of Hegel, the symptomatic reader (Althusser) may nonetheless discern an insurmountable break between the two oeuvres, in order to *force* Marxism to attain a clearer awareness of its own specificity.

Young Marx entered the scene in a particular intellectual world: the world of German ideology, haunted by Hegel's idealistic legacy. Germany was politically and economically underdeveloped compared to England and France, and this underdevelopment was *compensated* by ideological and theoretical overdevelopment. German idealism was part of this intellectual hypertrophy, this ideological compensation, lacking a solid grounding in real material problems. Marx's task was the rediscovery of real history beyond this enormous ideological layer, and this implied a *retreat* from German ideology (Hegel's legacy, now functioning as an ideological obstacle or *Hemmung*) and a *return* to the real history of capitalism and class struggle. Althusser now emphasises that this was not a dialectical process in the Hegelian sense: it was not a sublation or supersession ("*Aufhebung*"), nor an inversion or reversal ("*Umstülpung*", "*Umkehrung*"). It was a *rupture*: a prodigious *eruption* of real history into an ideological context. This put Marx on the track of his Long March, crossing enormous distances on his way to reality, sharpening his clinical sense, until he managed to publish his prodigious masterpiece *Capital*. Hegelian ideological overdevelopment had merely served as a propaedeutic: a training in the manipulation of abstract concepts structured as a system, *independently of its validity*. After the break, Marx founded a new discipline, opening up a completely new problematic, a completely new area of research.

This same idea is taken up, albeit in a more radical manner, in *Contradiction and Overdetermination* (1962/2005) where Althusser now definitely wants to rid Marxist discourse of the idea that Marxism is an "inversion" of Hegelian dialectics, shedding the ideological shell while retaining the dialectical core, – even though these are literally the terms in which Marx and Engels themselves describe their relationship to Hegel, the Master thinker of their youth. Althusser persistently denies that core Hegelian concepts (such as "negation", the "negation of the negation", the "identity of opposites", "supersession", the "transformation of quantity into quality", "contradiction", etc.) are still valid and functional in Marxist dialectics. These dialectical concepts now raise suspicion. We should no longer allow Hegelian schemata and formulae to "think for us". Key dialectical concepts, even though they are demonstrably borrowed from Hegel, are to be rigorously re-casted. Althusser now claims, for instance, that the Marxist conception of "contradiction" completely differs from its Hegelian precursor. In the case of Marxism, contradictions are *overdetermined*. This term (adopted from psychoanalysis) indicates that there are multiple interacting factors at work, and that causal relationships may shift and become displaced from one causal factor to the next. The latter mechanism is also called "metonymic causation", a term coined by Jacques-Alain Miller, combining the dialectical concept of *contradiction* with the psychoanalytic concept of *displacement* ("*Verschiebung*"). Furthermore, a sudden explosive accumulation, condensation and exacerbation of contradictions may give rise to a fusion, a revolutionary situation, as was the case in Russia in 1917. Althusser explicitly denies that this dynamic concurs with the Hegelian idea of a quantitative increase of tension which suddenly passes over into qualitative change. It is something "quite different": an irruptive dramatic rupture or mutation, rather than a supersession or sublation. It is not, as Engels phrases it, a parallelogram of forces building up a tension, but an unforeseen event ("événement"), without precedent.

This is taken up again in *On the Materialist Dialectic* (1963/2005), where Althusser again emphasises discontinuity, contrasting Marxist dialectics (science) with Hegelian dialectics (ideology), separated by a rupture. All dialectical concepts are to be completely reworked, as the theoretical practice of a science is completely distinct from its "ideological prehistory". The distinction between ideology and science takes the form of an "epistemological rupture", a concept Althusser borrowed from Gaston Bachelard (who supervised Althusser's Master's thesis on Hegel). Marxist dialectics entails practical political action in the advent of an emerging rupture, rigorously detaching itself from its ideological past, revealing this past as ideological. Prominent Marxists such as Engels and Plekhanov are now criticised because they merely *applied* dialectics, notably to the natural sciences, but a mere *application* is not a genuine *transformation*. Marxism as a theoretical practice has to struggle continuously against the ideology that haunts it, via theoretical and practical interventions that rigorously determine its own specificity. So far, Marxists active in fields such as law, religion, art and science used a Hegelian dialectic instead of a truly Marxist one, even if they proclaimed to conduct dialectical materialism. The specificity of their problematic was not yet rigorously defined: not as a *transformative* practice. Even Marx, although he practiced his dialectical method in *Capital*, never rigorously determined its logical and methodological specificity.

Marx wrote an impressive series of monumental books, but without ever writing a discourse on method, although it would have been quite valuable to us today, allowing us to address the problem of the specificity of the Marxist dialectic in a more rigorous manner. In *Capital*, we can see Marx's method in action, however, transforming ideology into science and knowledge. This method *is* the Marxist dialectic, but actively practiced, rather than theoretically determined. We lack a genuine "Logic", which Marx refused us, even though we know perfectly well that we have it, and where it is: in his dialectical works, in *Capital*, etc. We can find it there, but in a practical state, not in a theoretical state. Engels and Lenin knew this: they knew that the Marxist dialectic existed in *Capital*, but only in a practical state. The same goes for texts by Lenin, such as *What is to be done?* It is not a text on dialectics, rather a text written for immediate political use, but dialectics is actively at work in it.

What exactly is the problem with Hegel, according to Althusser? This is difficult to grasp in a rigorous manner because Althusser refrains from providing exact references to Hegel's work. He consistently refers to Hegel in a remarkably vague and general manner. Basically, Hegel is accused of seeing reality as a projection of the auto-development of the idea. For Hegel, Althusser claims, the movement of the idea from the abstract to the concrete is an auto-genesis of a concept. The point of origin is the abstract concept (in itself) which develops via alienation into an end result. This end product, however, is no more than its beginning. Hegel ignores the real transformations and discontinuities that constitute the political process. Hegel is not at all a political thinker. He imposes an ideological model: the model of the triadic development of interiority, the auto-genesis of the concept. Thus, instead of complexity, Hegelian dialectics envisions the auto-development of an original substance, the self-manifestation of an idea. Hegel is basically similar to Haeckel and fails to see the real in terms of overdetermination. For knowledgeable readers, however, is difficult to ignore the obvious tensions between Althusser's "image" of Hegel and Hegel's actual writings, with their emphasis on the importance of conflict, contradiction, drama, negativity and otherness, but this will be taken up later.

In addition, Althusser argues that, for Hegel, the material is merely an expression of the spiritual. Material nature is basically contingency for Hegel, which must be superseded by spirit. As a concrete example, Althusser (in concordance with Hegel's view that everything is a syllogism) refers to the American continent as a syllogism whose middle term – the Panama Isthmus – happens to be quite narrow, so that it is difficult for this continent to become a spiritual unity, although this is what should happen, dialectically speaking, for all differences must be negated, while segregation must be overcome and material contingency must be superseded. In Marxist dialectics, however, contradiction gives way to overdetermination, to structural complexity and unevenness. Change is now conceived in terms of mutation and transformation, condensation and displacement. Thus, contradictions become decisive, explosive and revolutionary. Every social formation is affected by unevenness, and the new situation is separated from the old formation by an insurmountable caesura.

Reading Capital

This same problematic is taken up in *Lire le Capital* ("Reading *Capital*"), a book resulting from a reading seminar at the *École Normale Supérieure*, parts of which were written by his pupil Étienne Balibar (Althusser & Balibar, 1965a, 1965b). Reading *Capital* is a challenging adventure, Althusser argues, not only because of the prodigious immensity of the book, but also because it is the protocol of a reading process itself. In *Capital* we see Marx actively at work: reading, assessing and transforming (intervening in) existing discourse (political economy).

Thus, Marx's *Capital* is important also from a methodological perspective. It is the paradigmatic protocol of a meticulous reading process, referred to by Althusser as "reading aloud" ("lecture à haute voix"). This prodigious protocol is now itself subjected to a meticulous reading process, "by the letter" (1965a, p. 10), by readers who follow an "oblique path" ("voie oblique", p. 10) through this immense discursive forest. The phrase "oblique path" indicates how Marx (and Marxist readers in general) adopts an "intentio obliqua": a philosophical "path" or method. "Method" literally means exploring or following a path ("ὁδός") together, reflecting on it, preferably in dialogue, as philosophical readers (μετ'+ὁδός). Althusser and his students at the ENS are underway to Marx, as it were, carefully exploring his concepts, his vocabulary, his logic ("λόγος"), his language. They read the book at least twice, the second time from an oblique perspective, focussing on the methodology of this research practice. Althusser's own book is a product, conveying the "experience" of an intense reading process.

Althusser and Balibar adopt a style of reading which, from the very outset, poses a question: the question concerning the *specificity* of Marx's discourse, the specificity of his dialectic, emphasising the difference with the ideological problematic of the early ("Hegelian") Marx, positing the Marx of *Capital* as the *real* Marx. *Capital* entails a dialectical reading of the discourse of political economy, Althusser and Balibar argue, but not in a Hegelian sense. An epistemological mutation or rupture separates Marx from Hegel (p. 11). *Capital* is an event, emphasising the gap between (Hegelian) ideology and (Marxist) science. Hegel is discarded as the ideological "pre-history" of Marxist science. According to Althusser, moreover, the epistemological model for their philosophical reading is not provided by Hegel (who sees reality as the progressive expression of the spirit) but by Spinoza, who had presented a critical method for reading the Scriptures in his *Theologico-Political Treatise*, likewise distinguishing ideology and mythology from science (p. 14).

One important ideological misconception to be discarded is the idea that science begins with observation of empirical facts. Reality, Althusser argues, is not an open book, waiting for us to be read. Rather, we tend to project ideological ideas on the real. Therefore, rather than with socio-economic facts, *Capital* commences with a meticulous analysis of established discourse, which inevitably results in a delay ("décalage", p. 14). Rather than analysing reality directly, philosophy first of all subjects established discourse to a rigorous reading procedure. The focus of attention inevitably shifts from things to signifiers, from "things in themselves" to discursive formations: to condensations and displacements. This discourse is not considered as the expression of the spirit, moreover. Rather, it is read in a *symptomatic* manner, focussing on the deficits, the inconsistencies, the lacunae and the gaps. This is how Marx reads political economy: not as a description of reality, but as a discourse whose deficits are symptomatic indications of the bourgeois ideology haunting it. This is how Marx reads authors such as Smith and Ricardo: focussing on the lacunae, on what is absent and remains unsaid, on what these authors fail to notice themselves, even though it is actually quite close at hand, for instance when they provide answers to questions they failed to ask.

This same "clinical" method was employed by Engels (in his "reading aloud" of the writings of Eugen Dühring) and by Lenin (in his critical reading aloud of Mach and the other empiriocriticists). Now, Althusser and Balibar employ this same method in their reading of *Capital* to discern the specificity of Marxist dialectic: its logic, its method (p. 35), making manifest what is already latently there (p. 37). More specifically, their intention is to show that Marxist dialectic is not an "inversion" of Hegelian dialectic, as Marx and Engels themselves phrased it, putting dialectics on its feet again, but something quite different.

This is developed further in *Lire le Capital* part two (1965b). Again, Hegelian dialectics is discarded as the ideological prehistory (p. 5) of dialectical materialism, while Marx's *Capital* is submitted to a *transformative* reading, resulting in more rigorous definitions of key concepts of Marxist dialectics, something for which Marx himself never had the time. Practically, these concepts are already there, but they have to be extracted ("herauslesen") as it were. This applies to the term "surplus value", for instance, which is something positive (something "extra"), but also something negative: something which is unseen and somehow missed by others. "Surplus value" is more than a mere word: it is a transformative scientific concept which exemplifies Marx's revolutionary conceptual system. Let this suffice as a brief presentation of Althusser's transformative reading practice, his intervention.

Reading Althusser

For those reading Althusser from a dialectical perspective, the radical "*Entzweiung*" or segregation of Hegelian and Marxist dialectics advocated by him (M_2) seems a rather dissatisfactory result (or even impasse) for various reasons. First of all because it is in contradiction, as we have seen, with how Marx and Engels themselves, in a plethora of literal statements and proclamations, determine their rapport with Hegel. In terms of the metaphor mentioned above: they always maintained the isthmus with the Hegelian subcontinent from which they came, seeing dialectical materialism as a materialisation of dialectics: an inevitable next step, but not a radical break. Moreover, the introduction of a rupture is only possible on the basis of a drastically reduced and impoverished version of Hegel's dialectical logic, utterly ignoring the dynamic complexities of his thinking. Hegel already emphasised for instance that the dialectical process never commences with empirical facts and that its first moment is always an unsatisfying discursive position already in place. While reading the sections Althusser devotes to Hegel, one inevitably wonders whether he ever really read Hegel. According to his comments in his autobiography, he actually read very little of Hegel, but the reliability of this source is disputable (if only because Althusser himself points out that an important objective of this autobiographic report was to show that his academic successes were built on “deceit”). According to this same autobiography, moreover, Bachelard (his thesis supervisor) did not really read Hegel either, nor Althusser’s thesis for that matter, although the examination resulted in an interesting discussion about whether it would make sense to replace Hegel’s (apparently Euclidean) concept of the *circle* with a more process- and system-oriented alternative, namely: *circulation*.

The question now is, would it be possible or desirable to supersede this caesura (as an intervention which forces us to discard Hegelian dialectics as such and start anew)? Would it be possible or even desirable to reconcile Hegelian and Marxist dialectics on a higher level of comprehension (thereby allowing us to reach a third position, M_3)? In the next section, this will be taken up by addressing the question what a specifically Marxist dialectical understanding of technoscience would amount to, as outlined by Althusser. In other words, would it be possible to determine, in a more precise and rigorous manner, the specificity of a Marxist (dialectical materialist) understanding of technoscience?

The Specificity of a Marxist Dialectic of Technoscience

In the previous sections we argued that the caesura posited by Althusser between Hegelian and Marxist dialectics is dissatisfactory. Separating Marx from Hegel seems only possible on the basis of a rather impoverished and schematic reading of Hegel’s work. In Althusser’s essays, Hegel’s oeuvre is obfuscated rather than brought to the fore. For Hegelians, it is difficult to recognise Hegel’s oeuvre in Althusser’s exposé. Althusser consistently reduces Hegelian dialectics to the autogenesis of a concept by completely ignoring Hegel’s emphasis on the importance of confrontation, negativity and otherness. Likewise, Althusser’s contention that the result of the dialectical process adds nothing to the point of departure, seems difficult to reconcile with Hegel’s actual views on transformation and change (which inevitably involve incorporation of conflicting viewpoints). Also, although Althusser redefines basic dialectical concepts such as contradiction, seeing it as “overdetermination” rather than as a “simple contradiction”, it is questionable whether Hegelian dialectics would block such an elaboration. In short, to the extent that Hegel is read with more care and precision, the positing of an “insurmountable gap” between Marxist and Hegelian dialectics becomes increasingly questionable.

This is not to say that we should completely *identify* Marxist dialectics with the Hegelian prototype. Rather, a more productive reading seems possible, allowing for a more rigorous and precise determination of the specificity of the dialectics developed by Marx and Engels. In other words, rather than starting from zero again, it seems more productive to determine exactly how Marx and Engels actually managed to take the Hegelian idea of a science of dialectics a decisive step further. To make this more concrete: what would be the added value of a Marxist philosophy of technoscience as envisioned by Althusser? I will first point to a number of strengths in Althusser's reading. Subsequently, I will point out some weaknesses as well.

Building on Marx and Engels, but also on Lenin and others, Althusser rightly emphasises that dialectics is a *practice*, and that a practice entails *transformation* rather than mere *application*. Thus, a dialectical assessment of technoscience should not only *interpret* scientific discourse as such, but should also result in *practical change*, affecting the way in which technoscience actually operates. And whereas Hegel's encyclopaedic oeuvre first and foremost entails a *historical* dialectic, a grand retrospective, resulting in a diagnostic of the present, a Marxist dialectics rather aims to develop a prognostic of the emerging future, preparing the ground for intervention. Finally, Althusser's most important claim is that transformations in the process of knowledge production do not begin with the discovery of new facts (1963/2005). Rather than addressing the real directly, there is always a moment of delay, as we have seen. The starting point of a scientific practice is a massive amount of written materials: established discourse. And a new science (a new technoscientific practice) can only emerge when this layer of materials is completely reworked. This process of knowledge production can be dialectically grasped and presented as follows:

M_1 (existing discursive materials and the *general* conceptual viewpoint they convey, A) → M_2 (transformation of these materials, subjecting this legacy to a critical reading procedure to demonstrate that it entails a *particular* ideological viewpoint, B) → M_3 (resulting in a series of validated concepts (e.g. "surplus value", "overdetermination", etc.) as a *concrete* product or outcome, E)

What is emphasised by Althusser is (a) the *ideological* nature of the initial problematic at work in established discourse; (b) the *transformative* impact of the critical processing of these discursive materials via symptomatic reading and (c) the scientific import of the results in the form of *validated* concepts. Thus, the decisive dialectical moment is a transformative practice ("symptomatic reading", or "reading aloud"), starting from established materials and resulting in concrete conceptual products. For Marx, who established a *particular* field of research, the British Museum was the optimal vantage point where the critical processing of established discourse could be practiced.

A similar structure can be discerned in other scientific practices as well. All research fields are subject to processes of transformation, so that a change in the mode of knowledge production results in outcomes which are *action-oriented* or *future-oriented*. This means, first of all, that technoscience is not a purely empirical endeavour and cannot be reduced to a mere registration of facts (data collection). The first task of a newly emerging scientific practice rather consists in a drastic reworking of the available materials (the representations, the concepts, the *Vorstellungen*) provided by previous practices, which are now exposed as ideological and biased. These representations are processed and transformed into validated concepts (as *products*) and this is basically the work of science. Science does not start with pure (objective) "facts". Rather, science challenges existing *general* concepts which now prove to be of an ideological nature. In dialectical terms, transformative criticism is the dialectical moment (M_2) when a particular knowledge producing practice is replaced by a more sophisticated one, giving rise to validated scientific concepts (as concrete universals, M_3), produced by scientific labour (brain work):

M_1 (*Vorstellungen*) → M_2 (transformation: Conceptual processing) → M_3 (validated concepts)

In short, according to Althusser, technoscience is a *transformative practice*, denouncing previous theoretical positions as ideological, and replacing previous worldviews with validated concepts. So far, contrary to what he himself suggests, the logic of his argument concurs with the basic structure of a dialectical syllogism.

The emergence of a scientific research field entails an "epistemological rupture", but this should not be considered a spontaneous event, as we have seen. Rather, it requires a series of interventions. A science must me rigorously developed and taught. Transformative action must be taken (the epistemological counterpart of the role played by Lenin's *What is to be done?* in revolutionary politics). A scientific research practice is not about application but about transformation, drastically modifying the means of knowledge production. It is not a reflection in retrospect on a fait accompli, but entails effective enactment.

Dialectically speaking, this is again in concurrence with, rather than in contradiction with, Hegelian dialectics. Science starts with *general* conceptions (M_1), which are subjected to a process of transformation involving qualitative change (M_2), while the outcome consists of *concrete* validated concept (M_3). Such a dynamic is discernible in an experimental design, for instance. What is *negated* by a particular experimental practice are the established convictions: the existing conceptual categories which are part of a broader ideological framework of concepts (M_1). These concepts themselves were the end-result of an extended historical process. They are never self-evident as such, and their apparent self-evidence is already an ideological symptom. In times of turbulence or crisis, Althusser argues, change will not take place spontaneously. Rather, the "spontaneous" response of scientists to a situation of crisis will be to retreat to established conceptual positions. In order to supersede the crisis ($M_2 \rightarrow M_3$), targeted interventions are required, and dialectics must be actively *practiced*. Technoscience does not emerge spontaneously, but must be actively organised as a transformative practice through conscious initiatives, which open-up new fields of research, driven by a problematic of their own, employing a different vocabulary, studying particular situations or exposing specific situations to particular conditions, resulting in validated concepts (M_3). Although this dynamic can be discerned in other research fields as well (cf. Lavoisier's critical intervention in eighteenth-century chemistry, to be discussed below), Althusser himself focusses on Marx's *Capital*, which can indeed be presented as a transformative process: reading, assessing and transforming existing discourse (political economy):

M_1 (political economy as an established discourse) → M_2 (exposed to Marx's transformative reading and critical textual processing) → M_3 (resulting in validated concepts, e.g. the concept of surplus value)

Again, whereas Althusser consistently posits an "insurmountable rupture" between Hegelian dialectics and Marxist science, such a claim seems difficult to uphold if we assess his actual analyses of the knowledge production process from a dialectical perspective. This means that we are evidently in need of a crucial test which may confirm or refute Althusser's claim concerning the incommensurability of Hegelian and Marxist dialectics. This test can only be provided by a concrete case study, a paradigmatic example of a Marxist analysis of a revolutionary scientific event, explicitly acknowledged as a guiding model by Althusser himself. As it happens, on various occasions, but most notably in *Chapter VI* of *Reading Capital*, Althusser refers to Engels's *Preface* to *Capital, Volume* Two (1893/1977), arguing that Engels's comparison between Marx and Lavoisier provides an optimal benchmark for a Marxist analysis of technoscience.

Friedrich Engels on Marx and Lavoisier

To further elucidate his Marxist understanding of science as a transformative practice (as opposed to ideology, which merely functions as a self-serving system of conceptions), Althusser (1965b, p. 6 ff.) uses a paradigmatic example of a dialectical reading process, which he also refers to elsewhere, namely Friedrich Engels' effort, in the preface to *Capital Volume II*, to elucidate the import of Marx's concept of surplus value by comparing *Capital* with Antoine-Laurent de Lavoisier's revolutionary work in chemistry. Lavoisier (1743–1794), Althusser argues, likewise represents an epistemological rupture between chemistry as a science and its ideological pre-history, prone to mystifications. Therefore, I will use this case history to elucidate the specificity of Marxist dialectics for understanding and transforming technoscience.

After 1870, Engels explains in his *Preface*, Marx' work on *Capital* came to a pause for various reasons, one of them being the fact that Marx (like Engels himself) became interested in modern science (geology, physiology, mathematics), a time-consuming detour, although other factors, such as health problems, fatigue and psychic depression played their role as well. The revolutionary import of Marx's work in political economy, Engels (1893/1977) argues, can be elucidated with the help of an example taken from the natural sciences. In 1774, Engels explains, Joseph Priestley announced that he had discovered "dephlogisticated air". He communicated his finding to Lavoisier who, triggered by Priestley's results, decided to subject phlogiston discourse to a critical review. And this resulted in the (delayed) discovery that Priestley had actually discovered a new element, namely Oxygen. This unleashed a scientific revolution, an "inversion", putting modern chemistry on its scientific feet (Engels, 1893/1977, p. 22).

For Althusser, this example first of all demonstrates Engels's "exceptional epistemological sensitivity", his "theoretical genius" and "extraordinary intelligence" (Althusser, 1965b, p. 9, 11). It was not the observation of a new fact, but Lavoisier's decision (triggered by Priestley's communication) to subject phlogiston discourse to a transformative reading which revolutionised chemistry. And this rereading resulted in the insight that Priestley's inability to realise what he had actually discovered was due to his failure to free himself from the conceptual categories of phlogiston chemistry. Lavoisier's intervention gave rise to a completely new scientific nomenclature, to a completely new set of validated concepts. Lavoisier actually founded a new science. According to Althusser, Engels's *Preface* entails a first sketch of the concept of the break ("coupure", 1965b, p. 16): a mutation through which a new science is established, based on a new theoretical matrix, distancing itself from its ideological prehistory. Similarly, and again in accordance with Engels's "luminous formula", Marx had distanced himself from Hegelian idealism, Althusser argues.

One obvious problem of this rereading of Engels's *Preface* is, that it is highly questionable whether Friedrich Engels himself would have agreed with Althusser's interpretation. Rather, Engels' "luminous formula" seems fundamentally in accordance with Hegelian dialectics. In fact, he had been rereading Hegel's work, notably his *Logic*, in parallel to his inquiries into the natural sciences, until his responsibilities as editor of the two posthumous volumes of *Capital* forced him to suspend his project (the "dialectics of nature") as we have seen. Dialectically speaking, phlogiston chemistry was both confirmed and challenged by Priestley's experimental results. His results seemed to amount to a *negation*, to something negative, to absence ("*de*-phlogisticated air"). For Lavoisier, however, this negation became the *stimulus* which triggered him to critically reconsider the phlogiston concept as such, on which the chemistry of combustion was grounded. And this resulted in a dialectical turn ("*Umschlag*"), in the sense that negativity passed over into positivity: a positive (affirmative) result, namely Lavoisier's awareness that Priestley's discovery was not something *negative* (a privation, an absence, a "*nicht*", indicated by the prefix "de-"), but that he had actually discovered something *positive*, namely a new element: Oxygen (O_2).

Thus, in contrast to Althusser's apodictic statements, this concrete case history actually demonstrates that a dialectical isthmus still bridges the apparent gap between Hegelian idealism and Marxist materialism. Starting point for the revolution in eighteenth-century chemistry was existing chemistry discourse (M_1), revolving around the phlogiston concept, developed to grasp ("begreifen") phenomena of combustion. The term "begreifen" is important here because it indicates that scientific research (as Marx emphasises) actually entails an appropriation ("Aneignung") of the real. Work in chemistry involves a continuous *interaction* between conceptual elaborations and experimental exercises. At a certain point, Priestley claimed to have provided additional empirical confirmation for phlogiston theory by producing dephlogisticated air in his laboratory. Paradoxically, as we have seen, the existence of phlogiston is demonstration by its absence.

For Lavoisier, however, this experimental result rather points to a disconnection, a *décalage* (M_2), between the object of knowledge (phlogiston) and the real object. A confrontation of phlogiston chemistry with the real is conducted, on the theoretical level (via a critical and systematic *rereading* of phlogiston discourse) but also on the practical level (by carefully designing and conducting hands-on experiments), resulting in the discovery of Oxygen (O_2). Rather than discovering negativity and absence (of phlogiston), a new element is discovered, exemplifying a new episode in the history of chemistry, a new mode of chemical knowledge production. This result (O_2) is still a symbol, a signifier (signifying an object of knowledge), so that the tension between Oxygen as a chemical element and "real Oxygen out there" is still in place. Oxygen is not something which can be literally grasped or seen. Nonetheless, compared to phlogiston chemistry, the O_2 concept is a more convincing effort to appropriate the noumenal real, a more viable procedure to reveal what, literally speaking, remains unseen: the molecular composition of air.

Phlogiston chemistry (the questionable starting-point) was effectively *negated* in the course of the process. In other words, the discovery of Oxygen was itself a syllogism: a critical reconsideration of existing discourse (M_1), which was exposed to rigorous rereading in combination with an experimental practice (M_2), gave rise to an important positive result, the negation of the negation (M_3): O_2 first of all, but also a new way of conducting research in chemistry, putting chemistry on a scientific footing ("on its feet"). Oxygen is the negation of the negation. Something allegedly negative (dephlogisticated are) is transformed into something positive (a dialectical reversal), while phlogiston chemistry is sublated into modern (scientific) chemistry. The rupture is actually a dialectical moment in the sense that the negation (of phlogiston chemistry) has a positive result (modern chemistry as the negation of the negation). In short, Lavoisier's revolution (as described by Engels) exemplifies the dialectical understanding of technoscience (as Engels already argued), allowing us to explain how dialectical materialism continues to build on Hegelian dialectics (the dialectical method or logic) while at the same time reversing it, by more consistently paying attention to the material and technological aspects of technoscience (i.e. the technical modes and means of knowledge production). Thus, while Althusser's reading is problematic (apodictic rather than dialectic), a dialectical rereading has a positive result, in the sense that Althusser's intervention allows us to further develop the specificity of a dialectical understanding of technoscience. Not only Marxist concepts (such as "appropriation") but also concepts such as "overdetermination" (borrowed from Freud) and *décalage* (delay or dislocation) may be incorporated as conceptual components of a materialist mode of dialectical research, not merely as additional tools, but as transformative contributions to the ongoing development of dialectics as a transformative and self-transformative practice.

This also applies, as we have seen, to Marx's dialectical analysis of production and consumption in the 1857 *Introduction*. Marx's analysis demonstrates how production and consumption constitute a "syllogism", how production inevitably passes over into consumption ("productive consumption") and vice versa: an analysis which is not only compatible with, but also constitutes a further elaboration of Hegel's dialectical logic, reflecting Marx's dialectical skills. In other words, the specificity of the dialectics developed by Marx and Engels can be more rigorously determined when we see their contribution as an important next step in the process initiated by Hegel: as an effort to *transform* dialectics from a scholarly technique into a scientific practice. Hegelian dialectics is not the auto-development of a concept, but a dynamical and interactive process, emphasising the indispensable role of otherness and negativity. Marx, Engels and Lenin, but also (ironically perhaps) Althusser allow us to elaborate this research program further. In the final section of this chapter, we will discuss to what extent concepts such as overdetermination, displacement and metonymic causation may be incorporated in dialectics as a research program. First, however, we have to come to terms with two remaining (allegedly insurmountable) obstacles identified by Althusser, namely the distinction between the object of knowledge and the real object (emphasised in *Reading Capital*) and the ideological nature of Hegelian dialectics as posited in *Philosophy and the Spontaneous Philosophy of the Scientists* (1967/1974).

The Object of Knowledge, the Real Object and the Problematic of Technoscientific Appropriation

The third section of Marx's *Introduction*, written in 1857 and presenting Marx's methodology in outline (1939/1983, p. 34 ff.), is an important point of reference for *Reading Capital*, as we have seen. Here, Marx explains that, while political economists start from the empirical real as a living totality, to analyse it in terms of categories and concepts, the method of science is to move in the opposite direction (p. 35, 632): from concepts to the real. Scientific research for Marx is an *appropriation* of the real and the path or method which leads from abstract to concrete is the method (pathway) of thinking. At first glance, this seems in perfect accordance with Hegelian logic (the syllogism of research), which likewise moves from a general conception (A, M_1) via a particular mode of questioning (B, M_2) to a concrete result ($A \rightarrow B \rightarrow E$).

According to Althusser (1965a), however, this is not at all the case. Although this may not be literally visible in the text, Althusser contends, Marx aims to posit an "insurmountable distinction" between being and thinking, between the real object and the object of knowledge, between natural processes and processes of knowledge production. For Althusser, this does not entail a relapse into idealism (e.g. the segregation between the phenomenal and the noumenal), because thinking is not something which can be attributed to an individual (psychological) subject or a transcendental (epistemological) subject (1965a, p. 47). Thinking is a function of a particular system, an apparatus of thinking, a particular mode of knowledge production, emerging in a particular historical context. Thinking is not done by individual subjects. Rather, it is the system which assigns to them the type of questions they may pose and the type of experiments they may conduct (p. 48). Thinking is the transformation (“*Verarbeitung*”) of representations into concepts (“*Begriffe*”).

The aim of *Reading Capital* is to determine as rigorously as possible the specificity of Marxist dialectics, emphasising the difference with Hegelian dialectics (1965a, p. 35). Although Marx and Engels themselves see their dialectics as an “overturning” (“renversement”) of Hegelian dialectics, Althusser argues that this answer suffers from an internal lack (“manqué intérieur”, 1965a, p. 35). For Althusser, “*Umkehrung*” is a word which is conceptually deficient. Therefore, instead of a literal reading, what is required is a reading which opens up a text that is still haunted and obfuscated by Hegel’s “ideological” heritage. In other words, the aim is to reinforce the rupture as a step that was prepared by Marx and Engels, but which they themselves failed to make. While Hegel (as an idealist) saw the real as resulting from thinking, Althusser contends that Marx’s discourse on method allegedly introduces an “absolute distinction” between the real object and the object of knowledge (1965a, p. 46). Although this may seem a relapse into the distinction between the noumenal and the phenomenal (as developed by bourgeois theories of knowledge), Althusser takes care to avoid such an “ideological” phrasing. The processes of production of knowledge must be segregated from real historical and natural processes. First of all, knowledge production should not be regarded as the cognitive activity of an individual subject (i.e. the epistemological version of the Robinson motif), but as the activity of a system: a particular mode of knowledge production, involving particular contrivances, technologies, social relationships, etc. This system is structured in a particular manner and its function is to transform existing materials (discourses, concepts, representations) into a consistent network of validated concepts. Thus, the starting point of the process of knowledge production is not a real original object, but an established body of ideological materials (something which belongs to the realm of thinking). And rather than looking at the history of science from a teleological perspective (where, in retrospect, the past allegedly progresses towards the present), we must learn to look at history as a series of ruptures or radical discontinuities, moments in time when a particular logical regime suddenly gives way to a subsequent regime. Althusser mentions the work of Georges Canguilhem on the concept of the reflex and the work of Michel Foucault on the clinical gaze as examples of such ruptures (p. 52).

Moreover, a rupture or discordance is posited between the logic of a particular mode of knowledge production and the logic of the real. Whereas Hegel claims that the logic of the real and the logic of human rationality are fundamentally identical (the real is rational and the rational is real), Althusser claims that Marx’s theory of knowledge starts from a rigorous non-correspondence between knowledge and the real (p. 55). The categories of human knowledge are determined by an apodictic logic of their own. Thus, whereas Marx himself claims to borrow his dialectical method from Hegel, Althusser claims that Marx (unconsciously) breaks with Hegel (p. 61).

This “transformative reading” seems difficult to uphold. What Marx is actually arguing is that the scientific method cannot be equated with induction. Science does not begin with a real totality (the world out there), but rather with basic concepts which are systematically developed. This does not mean, however, that science functions in a purely apodictic and deductive (Spinozist) manner ("more geometrico"). Quite the contrary, Marx explicitly emphasises the continuous *interaction* between knowledge and the real, also in the *Introduction*, most notably by emphasising that science is a systematic effort to *appropriate* the real. All instances of production, Marx argues, entail an appropriation ("*Aneignung*") of nature (p. 23, 619), and scientific knowledge production is a particular mode of appropriation. As Hegel points out, this is emphasized by the etymology of the term *Begriff* (the verb "begreifen" → "greifen" literally means "to grasp", and the term "concept" comes from the Latin verb "concipere": to take in, to hold). Thus, although Marx (in accordance with Hegelian dialectics) starts from concepts which are to be developed (M_1), the next step in the process is a moment of interaction and mutual exposure between the concept and the real (M_2). Knowledge entails a particular mode of appropriation of real objects (p. 65) and experimental research can be regarded as a particular mode of appropriation, an interactive and transformative mode of thinking. This evidently refutes Althusser's remarkable claim that, allegedly, according to Marx, knowledge and the real should be regarded as two completely separate realms. Somehow, therefore, Althusser must get rid of the term "appropriation", which seems to provide a dialectical isthmus, connecting knowledge with the real, and Marx with Hegel, and therefore problematising the idea of a complete rupture (both between Marx and Hegel and between the logic of knowledge production and the logic of the real).

Althusser repeatedly admits that the question of appropriation (science as a transformative mode of appropriating the real object, resulting in an object of knowledge) has to be posed (p. 66, 67). And he also admits that the dialectical answer to this question seems obvious: the natural sciences realise their aim by appropriating the real object via a specific mode of interaction, namely: *experimental praxis* (p. 68). Yet, remarkably, this answer is rejected as "ideological" (as anything not in agreement with Althusser's reading is discarded as "ideological"). According to Althusser, scientific practice is a processing of concepts which strictly remains within the conceptual / discursive realm: there is no genuine interaction with the real, while the validity of knowledge claims is assessed *exclusively* on the basis of internal logical criteria (p. 71). Strictly speaking, there is no such thing as experimental verification (p. 72). Knowledge is produced by the system, the conceptual apparatus, on the basis of its own criteria. The idea that science appropriates the real through experimentation and interaction is an illusion. There always remains a gap or dislocation (*décalage*, p. 76).) between cognitive processes and real processes, e.g. between the work of a geometer in the literal sense (e.g. a surveyor) and the earthly real, between biology and the living real, etc.

Is Althusser's argument convincing? Although my answer will ultimately be that this is not the case, let me first point to a number of strengths in Althusser's procedure, before highlighting the fatal weaknesses. First of all, Althusser is right to point out that, for Marx, the pathway of science does not begin with empirical observations (induction). Rather, abstract categories become increasingly concrete, so that the end result consists in a concrete totality, an interrelated multitude of relations and determinations (i.e. a system). Also, it is a strength to emphasise that technoscientific research is not the work of a single individual, and that the Robinsonade is not an adequate epistemological model. Technoscientific research involves a particular mode of knowledge production, and this not only includes laboratory technologies, but also funding schemes and organisational designs. And yes, dialectics emphasises disconnection (*décalage*) between thinking and being, between theory and practice, between cognition and the real, between biology and the living, etc., but as a crucial *experience*: a negative experience (triggering disappointment and discontent among practitioners), but also a stimulus for further research towards convergence, fostering continuous interaction between science and the real, biology and the living, until a concrete and validated understanding is attained (albeit always open to future problematisations).

A first weakness is the claim that being and thinking (the real object and the object of knowledge) constitute two completely separate realms. Marx (and this also applies to Engels) sees research as a practice and emphasises the *interaction* between both realms. Science is an appropriation ("*Aneignung*") and transformation ("*Verarbeitung*") of the real. The issue of Hegel's "illusion" is also taken up by Marx. Can categories have an independent existence? Marx answers this question in French "Ça dépend" ("That depends", p. 36, 633). Rather that positing a distinction between logical categories on the one hand ("thinking") and their historical or natural existence on the other ("being"), Marx himself emphasises how legal and economic developments always involve an *interaction* between categories and concepts on the one hand and concrete historical settings and developments on the other. The concept "possession", for instance, although being a bourgeois concept, may nonetheless allow us to understand that certain pre-historic societies may have had "possessions", but not in the modern sense of (private) "property" (p. 36, 633). Likewise, although "work" may seem a perennial concept (an inherent part of the human condition), *modern labour* is actually a fairly recent category. And while agriculture already began thousands of years ago, capitalism effectively transforms it into an agricultural industry (p. 41, 638). In short, rather than positing *being* and *thinking* (practice and concept, the real object and the object of knowledge) as separate realms, Marx emphasises continuous interaction between the two: between the real and our knowledge of the real, between historical modes of production and the categories of discourse.

From a dialectical perspective one could argue: without interaction, no disconnection (no "*décalage*"). The experience of *décalage* emerges precisely where concordance between thinking and being is expected, but for some reason cannot be achieved, an anomaly if you like. In other words, *décalage* can only be meaningfully experienced in the context of interaction (experimental or otherwise). It is an inherent and inevitable component of the technoscientific effort to appropriate the real:

Discursive development (M_1) → the technoscientific effort to appropriate the real, giving rise to the experience of *décalage* (M_2) → concrete knowledge as a precarious product of the interaction between theory and practice (M_3)

For Althusser, however, the experience of *décalage* implies that this third moment can never be reached and access to the real through interaction is blocked. There is no genuine interaction between the cognitive and the real. But this is explicitly in contradiction, not only with Marx's own statement, but also with the structure of *Capital* as such, which combines conceptual elaborations with a critical analysis of economic discourse (i.e. theoretical and historical analyses) in an interactive manner.[2]

Like Hegel, Marx distinguishes two closely interrelated dimensions: the current *system*, the current mode of production (the intrinsic *logic* of capitalism) and the *history* of the present (the dialectical process that gave rise to contemporary capitalism as a *result*). According to Marxist dialectics (and in accordance with Hegelian dialectics) previous stages are *superseded* by subsequent systems: a dialectical process of continuity and discontinuity, of quantitative and qualitative change. For Althusser's intervention (positing a rupture between the two) to work, he has to deprive words such as "inversion" and "appropriation" of their content, which is a questionable procedure. "Inversion" means that the focus of attention shifts from scientific ideas to technoscientific practice (i.e. the practice of putting elaborated concepts to the test), while "appropriation" involves a transformative reframing of the object. An experiment is never a mere application of a theory. Rather, it is a transformative activity, both theoretically (challenging theoretical preconceptions) and practically (transforming real objects into modifiable laboratory entities). This dialectical dynamic is completely lost in Althusser's views on science, resulting in the (remarkably *undialectical*) claim that processes such as elaboration ("Verarbeitung") and appropriation ("Aneignung") do not entail any form of interaction with the real. Segregating theory from practice not only deprives research of its interactive dimension, but also results in a fatal epistemological obstacle or *Hemmung* for understanding and transforming technoscience. If we follow Althusser, science could never progress beyond conceptual elaboration (M_1), could never become *technoscience*. Science as an apodictic system could never dynamically evolve through practical interaction with the real. This dynamic interaction is precisely what is expressed in the claim that Hegel equals Spinoza "set in motion" ("Spinoza mit en mouvement": Althusser, 1965a, p. 114). If we endorse Althusser's non-literal reading, the validity of knowledge claims would be determined solely on the basis of the apodictic logic (the systematicity) of the conceptual system.

[2] This is also indicated by the famous quote from the 1857 *Introduction* that human anatomy contains the key to the anatomy of the ape. What Marx is arguing here (inspired by Darwin's theory of evolution), is that an understanding of contemporary society may provide a starting point for retrospectively understanding socio-economic systems from the past (p. 78), because the former (contemporary society) is a historical *result* (p. 79).

There is another objection to Hegelian dialectics brought forward by Althusser. For Hegel, all the elements belonging to a particular historical episode express a basic concept, which is present in all these elements. If this is the case, Althusser argues (Althusser, 1965a, p. 118), how it is possible that at a certain point, pioneers of science are able to discern that a new form of knowledge production is in the making, that the advent of a new episode is imminent? From a Hegelian dialectical viewpoint, this is because they are frustrated and restrained by an accumulation of disconcerting experiences, so that at a certain point the accumulation of anomalies give rise to qualitative change. This is a moment of crises, which can only be addressed via targeted interventions and, eventually, via supersession or sublation, which means that core cognitions and results of the previous episode are reconsidered, transformed and incorporated into a reformed way of thinking (a new spirit if you like). According to Althusser, this dialectical view on change should give way to the idea of a radical discontinuity or rupture. Only in this manner, a teleological understanding of the history of science (seeing the past as a pathway towards the present, and the present as a result of dialectical transformations in the past) can be eliminated. Again, Althusser opts for segregation, this time not between thinking and being (theory and practice), but between present and past. And again, this view on change is at odds with how not only Hegel, but also Marx, Engels and Lenin experienced the logic of intervention. For them, effective interventions are informed by a solid dialectical diagnostic of the present. Rather than demonstrating the existence of an "insurmountable rupture" between Hegel and Marx, Althusser himself seems to relapse from a dialectical into an apodictic mode of reasoning. This becomes even more pronounced in his lectures on the "spontaneous philosophy" of scientists, to be discussed in the next (penultimate) section.

The Spontaneous Philosophy of Science and the Experience of a Scientific Crisis

Philosophy and the Spontaneous Philosophy of the Scientists (1967/1974) consists of a series of *apodictic* theses or propositions, in a Spinozist rather than dialectical fashion, starting with the claim that a philosophical proposition is a "dogmatic" proposition (T1). Taken together, such propositions constitute a system (T7). The question what philosophy is, can only be answered by actually *practicing* it (p. 27), but for Althusser the basic objective of philosophy is to draw lines of demarcation between ideology and science (T2). Although strictly speaking philosophy lacks a specific object of its own (T4), philosophy addresses the totality of things, zooming in on the revolutionary developments in contemporary science, notable its frontier zones, where completely new research fields (e.g. biochemistry) emerge, developments which are posing a plethora of challenging philosophical questions. Currently, moreover, science is being completely reorganised into a global industrial research enterprise ("planification", p. 22) and philosophy must have something to say about this, although its interventions will not consist in offering solutions (T12). We are witnessing a revolutionary turning point, an event of global significance, a global cultural mutation.[3] Philosophy must intervene by distinguishing science from ideology, which is a hazardous task, if only because philosophy itself is haunted by ideology, affected by the current ideological conjuncture. For Althusser, philosophy is a battlefield in the Kantian sense ("*Kampfplatz*") between scientific and ideological, materialist and idealist tendencies.

It is against this backdrop that philosophy may intervene in a particular scientific research practice, where a "spontaneous" philosophy is always already at work. Notably scientific crises give rise to spontaneous philosophical activities among scientists. During the crisis which emerged at the turn of the century (around 1900), for instance, the spontaneous philosophy of science, represented by Mach and others, was anti-materialistic. Although these authors themselves considered their views as "revolutionary", they actually (but apparently unwittingly) revivified a branch of bourgeois idealism. As Lenin convincingly demonstrated in his intervention, their "spontaneous" philosophy was actually a return to Kant and Berkeley in disguise. Various ideological worldviews are lying in wait, eager to exploit moments of crisis, such as the apparent disappearance of matter in elementary particle physics, to the benefit of a spiritualist or idealist revival. Althusser notably mentions Bergson and Teilhard de Chardin in this regard. The latter is accused of exploiting the turbulent developments in research fields such as palaeoanthropology and evolution theory in favour of his Catholic faith. Rather than being eliminated by Enlightenment, such ideologies persistently await the onset of a scientific disruption which they exploit *ad majorem Dei gloriam*.

Therefore, a philosophical intervention must counteract these idealist and ideological tendencies, these ideological exploitations of experiences of crisis, which actually build on a long apologetic tradition of exploitation of science by philosophy in service of dominant ideologies. In the case of Pascal for instance, admirable work in mathematics and scientific experimentation was combined with apologetic religious treatises which aimed to exploit the tensions and contradictions of modern science in the service of his faith. And the same applies to Teilhard, Althusser argues, a palaeontologist and a priest, a present-day Pascal as it were. These spiritualist tendencies are never completely eliminated and always ready to resurge whenever the conjuncture provides the occasion. Suddenly, such voices claim that science is in dire need of a supplement, consisting of values that safeguard human dignity.

Meanwhile, the silent majority of researchers continues to work and produce results, Althusser contends, convinced that matter did not evaporate at all, but continues to subsist. These scientific workers continue to believe in the material existence of the real. In sharp contrast with his previous insistence on the difference between the real object and the object of knowledge (as discussed above), Althusser now suddenly seems to take sides with those (allegedly "naïve") researchers who, based on their daily experience of scientific practice, continue to believe in the real,

[3] As indicated, this is a common thematic among continental approaches (Zwart, 2020).

external and material existence of the objects of scientific knowledge. These scientific workers are the target of ideological exploitation, by spiritualist ideologies that question the validity of scientific knowledge and emphasise its boundaries. Philosophy, Althusser argues, must intervene in this struggle on behalf of the active brain workers and their spontaneous materialist convictions, to safeguard them against ideological exploitation and domination.

This argument is elucidated with the help of a case study: the inaugural lecture by biochemist and Nobel laureate Jacques Monod at the Collège de France in 1967, whose work focussed on DNA, described by Althusser as the "philosopher's stone" of the contemporary sciences of life (p. 123). In his reading of Monod's lecture, Althusser notices a symptomatic shift. Initially, Monod seems to adopt (as a scientist, that is: spontaneously) a materialist position, emphasising the material existence of DNA and the validity of technoscientific research methods. Biology studies the emergence of complexity in the course of evolution, while rejecting vitalism. Yet, at a certain point, there is a decisive turn, when Monod begins to describe how the biosphere gave rise to the noosphere, a higher level of complexity: the realm of spirituality and thinking, a term adopted from Teilhard. The use of the term noosphere, Althusser argues, is symptomatic, and rightfully triggers suspicion, because it indicates that Monod at this point becomes vulnerable to exploitation by spiritualism and idealism (represented by Teilhard's teleological worldview). Monod also endorses the claim that humans, while being a biological species (a product of evolution in the biosphere) are at the same time created by language ("*C'est le langage – le noosphère, l'Esprit – qui a créé l'homme*", p. 128). For Althusser, this move, this shift, this "inversion" from material life to spiritual existence (exemplified by the adoption of the seductive signifier "noosphere") is symptomatic of the extent to which modern biochemistry (and this even applies to Nobel laureates like Monod) remains vulnerable to ideological exploitation. By admitting that an axis of development can be discerned in evolution (towards increased complexity and the emergence of the noosphere) the concept of chance is transformed, so that it may function in a spiritualist (teleological) context (in the sense that selection promotes complexity, notably the development of a neo-cortex, which gives rise to the emergence of thinking and the noosphere, etc.). In short: the noosphere triumphant. Monod is unable to offer sufficient resistance to this idealistic tendency. Therefore, a philosophical intervention (e.g. Althusser's own critical review) is required. Monod's subsequent apologetics in favour of values is likewise considered symptomatic. Science has eroded traditional values, Monod argues, giving rise to alienation and disruption. Therefore, scientific research must be "supplemented" by values, preferably the ascetic values inherent in scientific practice (reliability, trustworthiness, scepticism, self-criticism, etc.).

This text once again presents us with a remarkable mixture or acute observations and problematic claims. Let us take stock by pointing out the strengths and weaknesses of Althusser's theses. On the positive side, Althusser rightfully argues that philosophy is a *practice* which addresses the totality of things, zooming in on contemporary technoscience (on the technoscientific revolution), notably in the frontier zones, where completely new research fields emerge, posing a plethora of challenging philosophical questions, while technoscience is under the sway of "planification", evolving into a global enterprise. We are witnessing a revolutionary turning point, an event of global significance, and yes, philosophy must have something to say about this. Philosophy remains a battlefield, as Lenin demonstrated, by showing how Empiriocriticism actually revivified an egocentric bourgeois ideology, questioning the materiality and existence of the real (as was extensively discussed in Chap. 3).

What is problematic and disappointing, however, is that Althusser's actual intervention consists of a series of highly problematic and self-contradictory claims, starting with the claim that "philosophy is dogmatic" (how can a dialectical practice be dogmatic?). His criticism of Teilhard de Chardin is likewise unsatisfactory and unjustified. Teilhard de Chardin is a truly dialectical thinker (Zwart, 2017; but this will be taken up in Chap. 7) whose concept of the noosphere is the result of a dialectical understanding of evolution and the history of human thinking. And is the symbolisation, obliteration, informatisation, datafication and spiritualisation of the real (entailed in the concept of the noosphere) not precisely the inherent tendency of technoscience as a global enterprise (planification)? What is quite remarkable is that Althusser's exaltation of researchers (brain workers) who, in their daily technoscientific practice, continue to believe in the real, external and material existence of the objects of scientific knowledge, seems in complete contradiction with Althusser's previous apodictic caesura (in *Reading Capital*) between knowledge and the real object (discussed above).

From a dialectical perspective, the position adoption by Althusser in *Philosophy and the Spontaneous Philosophy of the Scientists* is unsatisfactory for various reasons. His apodictic or even "dogmatic" intervention on the philosophical battlefield results in a series of demarcations, dichotomies and contradictions (*science* versus *ideology*, *materialism* versus *spiritualism*, *science* versus *values*, *materialist* tendencies versus *idealist* tendencies, etc.), where one of the two (materialism) is valued as positive, while the opposite position (idealism) is valued as negative, and subsequently discarded as "ideological". From a dialectical perspective, however, we should rather see such polarised oppositions as moments in a dialectical unfolding, which eventually give rise to a more dynamical understanding of technoscience as a practice and as a process. Starting point is indeed the "spontaneous" philosophy of researchers, actively engrossed in practicing their research, but also already aware of the philosophical niceties involved. They endorse a "materialist tendency", based on their daily experiences as practicing scientists, resulting in a persistent believe in the real existence of the technoscientific object (e.g. genes, elementary particles, etc.) and the validity of the scientific method (M_1). At the same time, a dialectical approach will point to numerous disconcerting experiences, indicating a sense of disconnection (*décalage*) between materialist conceptions and the real, between validated research methodologies and practical results (problems of replication and so on). Such experiences (refuted expectations, etc.) are an inherent part of daily scientific practice (M_2).

When this is radicalised into a scientific crisis, Althusser argues that the spontaneous philosophy of practicing scientists becomes vulnerable to ideological exploitation: the resurge of the Master signifier (M_1) as it were. As a first example of ideological regression he mentions the neo-idealism of Mach and the other empiriocriticists. As Lenin explained (cf. Chap. 3), a demarcation was introduced between experience and reality, between the object of knowledge and the real object, between the phenomena and the things in themselves, between thinking and being, between scientific research (as a social practice) and nature, etc.: the moment of "*Entzweiung*" (M_2). Althusser's argument that the "revolutionary" position of the empiriocriticists actually entailed a revivification of (bourgeois) idealism is valid (cf. Chap. 3), although a number of dramatic shifts must be acknowledged as well of course (from the dualism between ego and object in Descartes, via Berkeley's religious denial of the existence of external reality and the critical epistemology of Kant, which distinguishes the phenomenal from the noumenal *Ding an sich*, up to Mach, who basically re-adopted Berkeley's position, but now cleansed of its religious aspects). What is quite remarkable of course (in the sense of self-contradictory) is that precisely this position, which is now discarded as ideological, was endorsed by Althusser himself in *Reading Capital* as non-ideological.

On closer inspection however, is becomes apparent that the rupture which Althusser (in *Reading Capital*) initially posited between the object of knowledge and the real object, is now displaced by a different caesura. In the *Philosophy and the Spontaneous Philosophy of the Scientists* Althusser now posits an apodictic rupture between biosphere (a scientific concept) and noosphere (allegedly an "ideological" concept). But this intervention is again quite problematic. Precisely because of the inconsistencies of the neo-idealist position (immersed in contradictions, as Hegel would have argued), the scientific and philosophical challenge of twentieth century was to supersede (sublate) posited dichotomies (between thinking and being, knowledge and matter, the phenomenal and the noumenal, etc.) at a higher level of complexity, and this is precisely what "thinking scientists" such as Bohr, Teilhard, Monod and many others tried to achieve. Their aim was to update our concept of matter (rather than denying its existence), without relapsing either into bourgeois idealism or into crude metaphysical materialism. The time-old segregation between materialistic and spiritual dimensions of human existence is superseded via concepts such as the noosphere, understanding technoscience as a dramatic transformation of the biosphere into a noosphere (via processes such as symbolisation, informatisation and datafication of the living) while at the same time emphasising a moment of qualitative change (as thinking is no longer considered the product of the biological brains of individual researchers, but as the outcome of a collective, planetary "brain-like" network, operating through artificial intelligence, interconnectedness and distributed thinking). It is unclear why Althusser considers "biosphere" a scientific concept while discarding "noosphere" as ideological, for both concepts belong together and refer to one another (as dialectical moments), as will be argued more thoroughly in Chap. 7.[4] Although Althusser's

[4] Likewise, as Monod argues, the tension between objective (allegedly "neutral") science and "subjective" (or "outdated") values is superseded by the insights that science is inherently value-driven,

analyses often strike us as dogmatic and self-contradictory in many ways, some of his contributions may nonetheless still be of value when it comes to developing a dialectics of technoscience, provided we are able to move away from his apodictic ("dogmatic") approach and understand the emerging dichotomies as moments in a dialectical unfolding.

Incorporating Althusser

I will now briefly indicate how some of Althusser's insights nonetheless represent added value when it comes to developing a dialectics of technoscience: not as apodictic propositions, but as *results* (i.e. ideas that are validated in practice).

(a) *Philosophy is a practice*. The question what philosophy is, cannot be determined apodictically, but can only be answered by actually practicing it. Althusser rightly emphasises, moreover, that practicing philosophy is not a matter of application ("philosophical engineering") but rather of transformation. Philosophical interpretations are action-oriented and future-oriented. Philosophy is a transformative practice (and this includes continuous self-transformation).

(b) *Philosophy is first and foremost a reading practice*. Althusser characterises his own reading practice as "symptomatic reading", a way of reading which adopts an oblique perspective, by focussing on the processes at work, seeing textual archives as battlefields where various scientific and ideological tendencies collide. Symptomatic reading means "reading aloud", allowing the discourse at hand to speak for itself. At the same time, it is a form of reading which is sensitive to the contradictions, the lacunae, the unsaid. This tension can be resolved by seeing reading as a dialectical practice. The literal text serves as point of departure, and philosophical readers focus on the key terms and crucial phrases. At a certain point, the apparent coherence (M_1) of this body of documents gives way to the awareness that these texts actually constitute a precarious compromise between conflicting, perhaps even irreconcilable and incommensurable tendencies (M_2) and that the apparent coherence is actually the result of condensation, displacement and secondary revision. Flaws and contradictions may serve as indicators here. Instead of allowing these tendencies to think for us, they must be brought out into the open. The oeuvres of Pascal and Teilhard, for instance, may be regarded as strategic discursive ambiances where collisions between a negating scientific practice (e.g. paleoanthropological excavations) and a spiritualist worldview (Catholicism) are enacted (cf. Chap. 7). In such cases (e.g. Teilhard, Monod, etc.), it is clear that we are not dealing with a "spontaneous" philosophy in the "naïve" sense of the term, but rather with a

and that research methodologies contain an inherent ethic (of reliability, trustworthiness, responsibility, sharing of results, responsible data management, duties of care, etc.).

sophisticated effort (by a scientist who is also trained as a philosopher) to supersede the inhibitory tension (M_3).

(c) *Every science has a "logic" of its own*, a series of concepts or categories which are implicitly or explicitly at work in a particular research practice, providing guidance. The objective of a philosophical (oblique) reading is to bring this logic to the surface, revealing its antagonistic relationships with rival forms of logic. Again, this is not a purely descriptive, but a transformative endeavour, revealing how categories which are considered as starting point, are actually the result of an extended history. This applies to an egocentric philosophy of science, which builds on a particular type of myth, the scientific hero, a particular version of the Robinsonade, featuring the egocentric individual as a favoured or calculating researcher. Obfuscation of the genealogy (the socio-historical genesis) of such basic concepts is characteristic of ideology. In reality, research is a social practice, driven by the means of knowledge production at work in a particular socio-economic ambiance.

(d) *Key dialectical concepts* (such as "contradiction" for instance) *must be continuously validated and redefined*. Althusser rightly points out that contradictions tend to be overdetermined, a view which is closely related to the awareness that a societal system should not be envisioned as a series of monocausal relationships, but rather as a network of multiple interacting and interdependent factors and relationships. This is exemplified by the concept of metonymic causation, which basically means that causality can be displaced from one element to the next, so that a particular element can replace another element as causal factor. While contradictions or tensions tend to be subdued by displacement, in a moment of crisis condensation may give rise to a revolutionary rupture. These specifications are not at all at odds with Hegelian dialectics, where a linear understanding of causality already gave way to an interactive view (causation as "Wechselwirkung"). If all contradictions are conceived as interactions, each position works as a stimulus triggering its own negation, while there is an obvious connection between the concept of condensation and the dialectic of quantitative and qualitative change (a rise of tensions resulting in an erupting transformation) until a situation of relative stability is reached at a higher level of complexity.

(e) Althusser's work has added value for *our understanding of technoscience as an experimental practice*. First of all (and in contrast with the philosophy of induction), facts or findings are never the starting point, but always the outcome (product) of a dialectical process. Facts are produced (as is already indicated by the etymology of the term *fact*, which comes from *facere*, to produce). Rather, we start with the established convictions (i.e. discursive materials) which are challenged or negated by a particular procedure. The relationship between established convictions and (delayed) confirmation or verification is thematised by Althusser as "décalage", which may mean both dislocation and delay, thereby emphasising the inherent precariousness of experimental verification and replication. Rather than indicating an insurmountable gap between theory and practice, as is suggested in *Reading Capital*, the term "décalage" emphasises the unevenness of theoretical and experimental developments, whose dynamics may be significantly out of pace, so that they continue to challenge and stimulate or even hamper one another. This explains, for instance, why the neutrino (an elementary particle which is electrically neutral and whose mass almost equals zero) was theoretically discovered in 1930 and empirically detected in 1954, while the Majorana particle (predicted in 1937) still proves a challenging enigma for experimental research up to this day. Moreover, rather than endorsing technological determinism (seeing knowledge as a mere effect of the technologies in place), technologies emerge as specific components of particular modes of knowledge production, as elements in overdetermined networks of relationships: they are "called for", in the context of a research practice. Modern computers, for instance, may be seen as instances of *conversion*, enabling revolutionary change in how research is conducted, albeit not in a deterministic sense, because *displacements* play a significant role as well, so that computers may unexpectedly evolve from a calculation device into a communication device, or from a data management device into an enabling device for interactive and participatory research (e.g. crowdsourcing). The computer should neither be seen as a neutral means, nor as a deterministic force, but rather as a protean and co-evolving phenomenon in its own right.

(f) Being inherently dialectic, the development of technoscience may display dialectical patterns spontaneously as it were. As indicated, above, contemporary information and communication technologies evolve as protean components within complex, interactive networks, exemplifying converging and enabling technologies (Althusser's "condensation"), giving rise to revolutionary situations by affecting the mode of production, whose technological, theoretical, organisational, legal and managerial dimensions tend to develop at an uneven pace (Althusser's "overdetermination"), while their role may easily shift from calculation device to communication device and back (Althusser's "displacement"). Thus, a dialectical dynamic can be discerned in *in silico* (computer-based) research. At the same time, the dialectical perspective must be consciously and carefully developed. In other words, there is *a continuous interaction between the spontaneous dialectic of technoscience and dialectics as a practice of transformative assessment and intervention*.

The result of the rereading process is that Althusser is more dialectical that he claims and that, intentionally or unintentionally, his efforts allow us to further develop a dialectical materialist approach to technoscience, building on a dialectical *interaction* between Hegelian and Marxist dialectics.

References

Althusser, L. (1953/1997). A propos du marxisme/On Marxism. In G. M. Goshgarian (Ed.), *The spectre of Hegel: Early writings*. Verso.

Althusser, L. (1961/2005). Sur le jeune Marx (Questions de théorie)/On the young Marx: theoretical questions. In *For Marx*. Verso.

Althusser, L. (1962/2005). Contradiction et surdetermination (Notes pour un recherche)/Contradiction and overdetermination: Notes for an investigation. In *For Marx*. Verso.
Althusser, L. (1963/2005). Sur la dialectique matérialiste (De l'inégalité des origines)/On the materialist dialectic: On the unevenness of origins. In *For Marx*. Verso.
Althusser, L. (1964). Freud et Lacan. *La Nouvelle Critique, 161–162*(1964–1965), 88–108.
Althusser, L. (1965/1974). *Pour Marx*. Paris: Maspero.
Althusser, L. (1967/1974). *Philosophie et philosophie spontanée des savants*. Maspero.
Althusser, L. (1985/1992). *L'avenir dure longtemps, suivi de Les Faits*. Stock/IMEC.
Althusser, L., & Balibar, E. (1965a). *Lire le Capital, Tome 1*. Maspero.
Althusser, L., & Balibar, E. (1965b). *Lire le Capital, Tome 2*. Maspero.
Engels, F. (1893/1977). Vorwort. In K. Marx, *Das Kapital: Kritik der politischen Ökonomie II*. Dietz Verlag.
Lenin, V. I. (1976). *Philosophical notebooks*. Collected works 38. Moscow: Progress.
Marx, K. (1859/1961). *Zur Kritik der politischen Ökonomie*. Karl Marx Friedrich Engels Werke, Band 13. Dietz Verlag.
Marx, K. (1867/1979). *Das Kapital: Kritik der politischen Ökonomie I*. Dietz Verlag.
Zwart, H. (2017). From the nadir of negativity towards the cusp of reconciliation: A dialectical (Hegelian-Teilhardian) assessment of the anthropocenic challenge. *Techné: Research in Philosophy and Technology, 21*(2–3), 1–24. https://doi.org/10.5840/techne20176565
Zwart, H. (2020). *Styles of thinking*. Series: Philosophy and psychology in dialogue 2. LIT Verlag. ISBN 978-3-643-96300-0.

Chapter 6
Coming to Terms with Technoscience: The Heideggerian Way

Introduction

Imagine a group of philosophy students, about to complete a Master's program in continental philosophy, who are invited to visit a life sciences research laboratory, somewhere on a university campus. Having studied some of Heidegger's quintessential works, such as *Being and Time* and *The Question of Technology*, they suddenly find themselves exposed to racks of test-tubes and automated sequencing machines. Suppose that, thrown into such an "unworldly" lab environment, they ask themselves how to interpret their experiences in a Heideggerian manner.

On closer inspection, this scene is far from fictitious. Being a continental philosopher myself, having worked in a science faculty for almost two decades, I often conversed with philosophy students, versant in the oeuvres of Heidegger and other continental thinkers, who were suddenly challenged to develop a philosophical commentary on emerging trends in contemporary technoscience, be it quantum computing, neuro-imaging or CRISPR-cas9. How to bridge, in a meaningful manner, the distance that segregates the world of philosophy seminars from the world of high-tech experimental inquiry? How to convince philosophers that this is not an embarrassment which they should forego, but an opportunity for which they should prepare themselves? Philosophy, I will argue, desperately *needs* these exposures to the intricate realities of technoscience, while technoscientific inquiry is evidently *in need* of philosophical assessment, notably from a continental perspective. How to turn such mutual exposures into meaningful intellectual experiences for both sides: for technoscience as well as for Heideggerian philosophy?

Scattered across Heidegger's oeuvre, we find intriguing comments on contemporary science or *technoscience* because, although Heidegger himself did not use this term, he does emphasise the inherent technicity of science. For Heidegger, science (technoscience) is inherently technical, imbued with technicity, thereby precluding other (more poetic) ways of understanding nature (Glazebrook, 2012). What lessons can be derived from such comments for philosophers who are *on their way* to

H. Zwart, *Continental Philosophy of Technoscience*, Philosophy of Engineering and Technology 38, https://doi.org/10.1007/978-3-030-84570-4_6

questioning technoscience as it is practiced today? Can Heidegger's thoughts on science and technoscientific "things" become a source of insight and inspiration for philosophers who are confronted with automated sequencing machines, magnetic resonance imaging machines and other technoscientific contrivances?

As we have seen in previous chapters, this is closely related to the question of method. Although Heidegger himself was notoriously ambivalent concerning method, especially in his later writings, his oeuvre nonetheless contains important hints for how a philosophical questioning of technoscience could be practiced. For Heidegger, philosophy basically means: being underway. Could a site visit to a life science laboratory be part of a meaningful philosophical journey, *underway* to understanding technoscience? In a recent study on Heidegger and climate change, Vincent Blok (2020) argues that the "crisis" of contemporary philosophy (e.g. its inability to significantly contribute to addressing planetary environmental challenges) stems from "a lack of interest in the question of a philosophical method" (Blok, 2020, p. 17), and I agree with this claim. Heidegger, I will argue, provides many hints on how philosophers may learn the "handicraft" of thinking (1954/2002; GA8, p. 18) and this paper explores how these hints (*Hinweise*) can help to come to terms with technoscience.

Heidegger was well aware of technoscientific developments during his lifetime. As Joseph Kockelmans (1985) pointed out, Heidegger was well read in science, participated in scientific PhD defences and engaged in discussions with Heisenberg, Von Weizsäcker and others. As to direct personal experience, during the final months of World War I, Heidegger served in a meteorology weather service station, providing the German artillery and air force with systematic observations on temperature, air pressure, direction of the wind, etc., employing a range of measurement devices, first at the *Hauptwetterwarte* in Berlin (where he received an 8-week training course in meteorological logistics) and later at a *Frontwetterwarte* at the Western Front near Verdun. In fact, weather forecasting was one of the many research areas significantly boosted by warfare activities, as numerical processing and forecasting became increasingly important (Lynch, 2006). In 1922, British mathematician Lewis Fry Richardson published *Weather Prediction by Numerical Process*, based on his wartime experiences (Richardson, 1922/2007) and describing how during the war, large numbers of "computers" were at work upon the weather for a particular part of the map – where "computers" refers to humans, making calculations. Robert Musil's novel *Man Without Qualities* (*Mann ohne Eigenschaften*), published in 1930, may likewise serve as an indicator of the pervasiveness of meteorology, as it begins with a weather report.[1] To the best of my knowledge, the impact of Heidegger's exposure to militaristic meteorology on his understanding of

[1] "There was a depression over the Atlantic. It was travelling eastwards, towards an area of high pressure over Russia. The isotherms and isotheres were fulfilling their functions. The atmospheric temperature was in proper relation to the average annual temperature and the a-periodic monthly variation in temperature… In short, to use an expression that describes the facts pretty satisfactorily, even though it is somewhat old-fashioned: it was a fine August day in the year 1913" (Musil, 1930/1978, p. 9).

technoscience (and its connection with "mobilisation") and his own "atmospherology" (Wilde, 2020) has not been considered as yet.

The structure of this chapter is as follows. First, I will present an outline of Heidegger's views on method, both in early work and in later writings. Subsequently, I will explore Heidegger's views on technoscience, more specifically on technoscientific *things* (laboratory artefacts), on technoscientific *sites* (laboratories) and on technoscience as a global *enterprise*. The basic contours of a Heideggerian "method" for questioning technoscience will be fleshed out (recollected) "along the way". In the final section, the results will be assessed.

Heidegger on Method: Setting the Stage

In *Being and Time*, Heidegger thematises human existence as a lived practice, reminding us that in ancient Greece, things were regarded as πράγματα: entities we deal with in a practical, caring manner (1927/1977; GA2, p. 92). Could this apply to entities (neo-things) we encounter in laboratories, whose way of being seems questionable from the very outset? There is something artificial and unfamiliar about laboratory artefacts. We already raised the question what kind of a *thing* a test-tube is: this universal, uniform recipient, this inconspicuous non-object, which at the same time exemplifies the scientific strive for experimental transparency and control – as well as being a microbe's habitat? What kind of a *world* (or non-world) is a laboratory, where everything we associate with everyday existence is systematically kept at bay, including everyday conceptions and convictions? What kind of *existence* is science as a profession? What kind of *practice* is laboratory work? How do scientists stand out towards the *entities* they study? Do they study *things* at all, or rather laboratory artefacts? Which *metaphysical convictions* are guiding (are materialising in) laboratory life, or questioned by it? In terms of *questions* we must ask (the questionability of technoscience), we remain quite close to the questions addressed in previous chapters of this volume.

To address such questions, we must deepen our understanding of Heidegger's "method". Although the later Heidegger sees the quest for a rigorous method as symptomatic of the technoscientific enframing of nature as reproducible objectivity, the outlines of a method for philosophical reflection can nonetheless be discerned, also in his later lectures and essays, albeit a method that is developed *along the way*: gradually emerging as a road to follow, in accordance with the original Greek meaning of the term (μετ'+ὁδός). This outline entails important components, such as: paying attention to language, e.g. to the history of the terms we use. Other important components are the dialogue (*Zwiesprache*, *Auseinandersetzung*) with previous thinkers, the neighbourhood (*Nachbarschaft*) of poetry and thinking (compared to the distance between thinking and science) and the awareness of the provisional nature of our concepts, so that we are always *underway* towards language, knowledge, truth, etc. Also important is the backward step (the *Schritt zurück*), towards the moment of commencement (*Anfang*) of established ways of thinking.

Heidegger's "method" allows us to deepen our understanding of contemporary technoscience, as a transformative and disruptive force. But a reflection on contemporary technoscience will also enable and necessitate a renewed confrontation (*Auseinandersetzung*) with Heidegger's own thinking.

Rather than being a commentary on Heidegger's oeuvre, therefore, the aim of this chapter is to *extrapolate* Heidegger's way of thinking towards the present. How to practice "Heideggerian" philosophy today? The scholarship conducted here does not easily fall under the heading of "author studies". Rather, my purpose is to step back and reconsider Heidegger's efforts at developing his way of questioning and thinking. My question is not how Heidegger interpreted technoscientific developments in the 1920s or the 1950s. Rather, the question addressing us here is how to consider technoscientific things and practices from a Heideggerian perspective today? This requires a reconsideration of Heidegger's method. As was already indicated, his views on "method" shifted quite drastically over time. In *Being and Time* (1927/1977; GA2), for instance, but even more so in *Basic Problems of Phenomenology* (1927/1975; GA24), dating from the same period, Heidegger speaks about method in a resolute and affirmative manner. Phenomenology is presented as the *method* of the science of ontology, the philosophical method par excellence. In later writings, the very aim of developing a methodology is discarded as unphilosophical, technical and hazardous. Methodology becomes associated with technical and calculative thinking, with research as an enterprise.

The prospects for unearthing a "method" for understanding technoscience, notably from Heidegger's later writings, may seem discouraging. Although these writings contain many careful interpretations of things like jugs and clogs, technoscientific entities (such as Sputniks or atom smashers) are discussed in a distanced manner, without paying much attention to detail. A Sputnik, according to Heidegger (1959/1985; GA12, p. 165), travels at high speed through a non-world: through unworldly space, as an artificial entity. The question what kind of a thing a Sputnik really is, seems to be evaded.

In short, this chapter addresses the question how Heidegger's method allows us to question contemporary technoscience as a practice. I will focus on a particular realm (*Bezirk*) of technoscientific inquiry, namely life sciences research. How to consider, from a Heideggerian viewpoint, technoscientific entities such as genomes or automated sequencing machines? How to understand life sciences laboratories as worldly–unworldly settings, and life sciences research as a global enterprise ("*Betrieb*")? Or should we discard the very idea of a Heideggerian method for studying contemporary technoscience as an oxymoron from the very outset? My answer will be that a Heideggerian method of questioning can be developed *along the way* and that his lectures and writings contain important hints which put us on a viable track. For instance, a Heideggerian philosophy of contemporary technoscience should not be practiced as a form of "espionage" (1927/1975; GA24, p. 227). We should not study scientists in a secretive manner, "from behind". Could we study them from a position of proximity or "neighbourhood" (*Nachbarschaft*), so that philosophical reflection unfolds as a science-philosophy dialogue (*Zwiesprache*), along the way? In the next sections, Heidegger's views on method will be explored in more detail.

Heidegger's Early Views on Method

The issue of "method" is already addressed in *Being and Time*, where Heidegger (1927/1977; GA2) explains that a philosophical (phenomenological) method of inquiry entails an analysis of Dasein (human existence as *being-there*) and a "destruction" of the history of philosophy, enabling a *return* to and *recovery* of our primary experience and interpretation of being. Dasein is not presented as an isolated "thinking ego" facing an object, but as a form of existence structured by intentionality: dwelling in a world, standing out towards and uncovering concrete things, which are part of a coherent and meaningful ambiance. Most of the things we encounter are useful things, ready-at-hand, belonging to (and referring to) a particular context (a home, a workshop, etc.). We handle these things (πράγματα) in everyday practice, but philosophy (phenomenology) urges us to take a step backwards, to question and disclose their way of being. For instance: a glass (with a flat bottom) and a table (with a flat surface) *refer to* one another, as the glass is fashioned in such a way that we may safely put it on a table. They are part of (refer to) a particular setting or constellation. Before taking up a glass, we are already *there*.

If we extrapolate these considerations to contemporary life sciences research, the laboratory becomes an ambiance where entities such as test-tubes and petri-dishes, but also our practices of handling them, become part of a meaningful whole. By taking a step backwards, we distance ourselves from preconceived interpretations, such as the segregation between subject and object, natural entities and artefacts. We approach laboratory life from within, structured in a particular manner, entailing a particular form of intentionality.

Some of the things we encounter are put to use as signs or symbols. Heidegger uses a nice urban example from the 1920s: an adjustable red arrow used by truck drivers as a sign to indicate the direction in which the car is going to turn. We are not supposed to care too much about the sign as such (we should neither stare at it, nor ponder its construction) but rather be aware of the movement the vehicle is about to make. In short, we interact with and are addressed by multiple things in various meaningful ways. Philosophy (phenomenology) studies this world by analysing the ways in which these entities present themselves to us. Whereas some things can be used for certain activities in a certain manner, they also point beyond themselves towards the broader setting. This function of referral (*Verweisung*) may become formalised to such an extent that the thing becomes a sign or symbol (*Zeichen*), signalling things to come, or things at a distance (1927/1977; GA2, p. 104). They can only function as signs insofar as Dasein exists, however: discerning and interpreting them as signs. This again is something to consider when visiting laboratory settings, where many entities indeed function as signs: as signalling or measuring instruments, referring to something else, something which is not yet there, or which is kept in vitro. In other words, what applies to Dasein as such also applies to laboratory life: human existence is inherently connected to the way of being of the things we encounter and we recognise ourselves in our handling of them.

We encounter a similar view on method in *The Basic Problems of Phenomenology* (1927/1975; GA24), a seminar dating from the same year 1927. The aim is to learn students to *practice* phenomenology, to become practicing philosophers, to *join* the practice of thinking ("*mithandeln lernen*", p. 1). The focus is on the *How* of philosophical inquiry ("*Forschung*"). Phenomenology, Heidegger argues, is the method of a "scientific philosophy" (p. 3), allowing philosophy to become a science. Whereas the "positive" sciences study various types of beings, philosophy is the science of being as such: studying the *way of being* of beings in a systematic (phenomenological) manner. Phenomenological analysis commences with studying concrete beings, but from a sideways perspective as it were, focusing on their *way of being*. Phenomenologists may study a particular tree, for instance, not in order to understand photosynthesis, but because they are interested in the way of being of living beings. Being is only accessible *via* the analysis of concrete beings. The essence of the phenomenological method is the step backwards: from investigating concrete beings (the work of specialised sciences) towards questioning their way of being *as such*, so that being as such comes into view.

Thus, phenomenology studies the basic structure of particular ways of being. Dasein, for instance, is structured as Being-in-the-world, as *intentionality*: standing out towards other beings (things). Our intention is fundamentally oriented towards disclosing other beings. At the same time, we are what we do and we recognise ourselves in our handling of things in our environment. To understand craftsmen, we must visit their workshops. When we look at our watch, we do not see the watch as such, but are oriented towards things to come: the time we still have before a particular event takes place, unless we are watchmakers, for then we focus on the watch as such. We analyse Dasein via our interactions with our environment, requiring care and effort.

What lessons can be learned for understanding technoscience from these early writings? First of all, we see technoscience as a practice, unfolding in a concrete, meaningful context. We should not only *read* about science, but visit scientists in their laboratories (literally: workshops) to consider the ambiance in which technoscience is practiced and how scientists stand out to and are addressed by things. We have to be *there*, albeit in a particular manner. Philosophical reflection does not amount to "espionage" (p. 227), – which, perhaps, is how social scientists or STS scholars study science: seeing scientists and scientific practices as targets of research. Rather, the focus should be on the *intentionality* of the scientists themselves, on the *way of being* of the laboratory items handled by them. Are these entities tools, signs, artefacts? Do they constitute a particular form of objectivity? Scientists are studied by studying their research practice from within as it were: envisioning the things they handle, the extent to which they themselves *are captured by* and merge into ("*existierend aufgehen in*") these interactions. The things they intentionally handle may not yet be recognisable items, but laboratory artefacts: uncanny neo-things, whose *way of being* still has to be explored.

The most important methodological concept put forward by Heidegger in the1920s is the "formal indication" ("*formale Anzeige*"). The meaning of the phenomena we encounter cannot be fully disclosed, can only be indicated or hinted at in a provisional manner, so that their meaning must be explored more fully *along the way*. To start with an explicit definition would put us on a questionable track, endorsing accepted interpretations while obfuscating other possibilities. Although a formal indication initiates and guides the explication process, it does not entail any preconceived convictions. It is a precautionary measure (*Vorsichtsmaßregel*, 1920/1921/1995; GA60, p. 64). A formal indication is a revisable way of pointing to particular phenomena, deflecting from uncritical lapses into established interpretations that foreclose further explication (Dahlstrom 1994). Philosophical concepts are indications pointing to a concrete task, to be performed through philosophising while foregoing pre-emptive characterisations of the phenomenon's way of being. The phenomenon is not given as something already understandable, but can only *become* understandable via questioning and working through, bracketing customary ways of considering things.

The formal indication inverts the "normal" perspective, the mainstream way of posing questions, and opens up a movement of retrieval which runs counter to accepted (unquestioned) manners of capturing phenomena, notably in science. For Heidegger, the purpose of this reversal of the taken-for-granted attitude is to avoid the kind of objectification that characterises the positive sciences. Philosophical concepts are non-objectifying. Philosophy is re-iteration, retrieving the path (*iter*) towards the phenomena that call upon us, indicating a task to be carried out, via thinking as an exercise in retrieval. A continuous methodological reflection is inherent to this non-objectifying way of speaking and thinking. Formal indication is Heidegger's version of *docta ignoratia*.[2] We point to the phenomena at hand, whose meaning may *seem* self-evident, and to possible directions of interpretation, but in such a way that we at the same time acknowledge that we do not really know what we are actually saying when we use words such as "thing", "thinking", "being" or truth", and that we should allow ourselves to be summoned by these words, that we should be prepared to travel the difficult path towards them. Heidegger developed his notion of formal indication in the context of his *Auseinandersetzung* with Husserl (Hadjioannou 2019; Wendland et al. 2019) and the term "formal" (used in the context of his discussion of Husserl's concept of formalisation) actually means something like "provisional". Heidegger refrains from re-using this term in later texts, but the attitude as such remains very much alive, not only in *Being and Time* (Dahlstrom 1994, Streeter 1997, Shockey 2010), but also in later writings.

[2] Cf.: "Nur dies Eine ist zu wissen, dass wir nichts wissen, solange wir… etc." (Heidegger, 2009, p. 88)

Heidegger's Method after the Turn: First Exploration

In later writings (after the *Kehre*), Heidegger's attitude towards "method" seems to change dramatically. Whereas in 1927 he resolutely presented philosophy as a rigorous science, in later writings he rejected this idea: apparently a radical turn in his path of thought (Glazebrook, 2000). And whereas in earlier writings he seemed bent on developing a rigid method, Heidegger now identifies method with technology and the calculative rationality of the natural sciences. He emphatically discards "methodological considerations" in favour of the experience of authentic thinking (Heidegger, 1959/1985; GA12, p. 168). Indeed, the received view is that Heidegger abandoned the quest for a rigid method after the turn and that, in his late philosophy, his manner of proceeding is "relieved of the claim to be methodical" (Thomson, 1999, p. 170). In contrast with his earlier emphasis on the importance of method, Heidegger now appears to reject the very idea of a "philosophical method" as oxymoronic (p. 171). Although the term method is derived from ὁδός ("the road, the way"), in Heidegger's later writings, the gap between his own "way" of thinking (off the beaten track) and the "methodology" of the positive sciences seems to widen (Von Herrmann, 1990).

Or should we rather say that the claim that the later Heidegger has no method is mistaken, and that his later writings contain important methodological reflections (Dahlstrom, 1994, p. 779)? In the following sections, the latter option will be endorsed. Heidegger's aim, I will argue, is to recover a forgotten (albeit non-technical, non-procedural) understanding of method as "being underway" (cf. Thomson, 1999, p. 174), pursuing ("*nachgehen*") the way of thinking, the path of our words (as a "Sprachweg", cf. Weibel, 2009). Heidegger's later writings contain important hints for a new beginning, also where method is concerned, pointing out a new way of practicing philosophy, even though he remains adamant in his refusal to adopt the term "method" for his approach. Similar to Gadamer (1990), Heidegger's reluctance towards method should not be considered as a denial of the importance of methodological concerns, but as an insistence on philosophical understanding as an explorative, dialogic, practical and situated activity.

One important methodological hint is that we should carefully listen to and pay attention to language (1959/1985; GA12 and elsewhere). Language speaks, and in order to experience the voice of language, and to become sensitive to the way we are addressed by language, we should pay attention to the genealogical vicissitudes of the words we use, so as to discern and recover their primary meaning, which eroded over time, although their original meaning somehow still shines through, even in our perverted and inconsiderate use of them.

Closely connected with this is another important dimension of Heidegger's way of thinking, namely his recourse to the first beginnings of Western philosophy,[3]

---

[3] See for instance his rereading of sayings by Parmenides, Heraclitus and Anaximander in GA5 and GA7. Heidegger's "Rückgriff auf den ersten Anfang der abendländischen Philosophie" (Gadamer, 1990, p. 261).

Heidegger's recurring efforts to recollect and rethink the daybreak of early Greek thought, his attempts to reread the sayings of ancient Greek thinkers in such a way that their language becomes audible again, is brought nearer to us again, so that, to some extent, their groundbreaking thoughts become thinkable (accessible) again.

Another hint is to pay attention to poetry, to the language of the poets, not any kind of poet, but the "daring" ones, who dare to expose themselves to the address of language (1946/1977; GA5, p. 316, 318). Lines of Hölderlin poetry are read in the same careful manner as Heidegger reads (recollects) sayings by Heraclitus or Anaximander. What is obfuscated in calculative rationality, may be retrieved in poetry. Science itself has fallen under the sway of technology, but appears to be unknowing of its own predicament. We should therefore consider the poetry of daring, untimely poets in a thinking manner, sensitive to how their poetry reveals a more poetic way of encountering things, or even the secret of being as such. Poetic art may prepare the way for a new beginning, instigating a new "method" even: a radically new way of philosophical questioning (Blok, 2015, p. 6, 2020, p. 28).

Heidegger also endorses the phenomenological adage "To the things themselves", but in a way that is different from Husserl. While for Husserl the translation of *Sachen* with "things" is somewhat misleading, in Heidegger's works we find multiple efforts to approach and come to terms with concrete, tangible things, like hammers, clogs and jugs, in a sensitive, careful manner, so that our questioning of them does not amount to an assault upon them (Owens, 1987).

Can we consider such hints (e.g. pay attention to language, listen to thinking poetry, heed the way in which daring poets allow language itself to speak, step back to recollect the commencement of Western thinking, etc.) as points of departure for coming to terms with technoscience? They outline a path whose orientation seems fairly remote from the experimental practices that are actually conducted in laboratories of contemporary life sciences research. An important motive for Heidegger's later resistance to "method" is his identification of the term with the *methodology* of technoscience: technical procedures for procuring quantifiable results, enframing nature as a mere resource for exploitation. Whereas the later Heidegger fosters proximity (*Nachbarschaft*) between poets and philosophers, the science-philosophy divide widens.[4] The way in which thinking poetry and poetic thinking allow the world to appear (allow things to present themselves to us) seems juxtaposed to the way in which technoscience *obliterates* its objects, to the way in which technical power reduces things to mere "objectivity".

On the other hand, precisely this gap or tension, between poetry on the one hand and calculative, technoscientific rationality on the other, seems to call for something like a "comparative phenomenology". Whereas Heidegger speaks about poetic, rural, artisanal things (like jugs and clogs) in a detailed and careful manner, technoscientific entities are mentioned in passing. Heidegger mentions "this thing Sputnik", for instance, this miracle and dream of modern technology and planetary computing

---

[4] "[Es] gilt zu erkennen, dass der Abstand zwischen dem wesentlichen Wissen und den Wissenschaften ein unendlicher ist. Hier gibt es keine Brücke" (Heidegger, 2009, p. 118).

(1959/1985; GA12, p. 165) that travels at very high speed through world-less space, lighting up momentarily in Heidegger's own text, but without being really considered. Why is this entity, this high-tech novum of planetary significance, not fathomed in a much more careful, extensive, *methodological* manner? If, in earlier works, Heidegger discusses urban technical entities such as traffic signs (1927/1977; GA2, p. 78) or the Marburg central train station (1927/1975; GA24, p. 98), what is now holding him back? What is the reason for this withdrawal? If the aim of philosophy is to come to terms with the present (and the planetary hazards entailed in the current situation, the current global crisis), why not question the enigmatic *way of being* of Sputniks and other technoscientific contrivances (besides, and in contrast to, the way of being of jugs and clogs)? Indeed, why not analyse Sputniks *first and foremost*? How to acquire a more precise understanding of the vicissitudes of technoscientific objects in the context of scientific research as an objectifying praxis?

Heidegger's phenomenology is hovering mid-way between two contrasting perspectives. On the one hand, Edmund Husserl's phenomenology – reflecting extensively on Galileo's impact on the mathematization of the lifeworld, for instance, but without considering Galileo's research contrivances: neither his elaborate experimental set-ups with inclined planes, nor his telescope (cf. Ihde, 2011). On the other hand, post-phenomenology, with its "excessive" focus on concrete artefacts (cell phones, GPS, fMRI, pacemakers, etc.), thereby tending towards an empirical (sociological, ethnographical or STS) approach. Should we choose between these two positions, or is there a "Heideggerian" alternative, a middle ground? Whereas post-phenomenology explores the cultural and mediating role of artefacts in the life world, this volume focusses on research contrivances, on the technicity of technoscience as such. Can Heidegger's method be of help here?

Heidegger's Discourse on Method: On our Way Towards Technoscience

As a first introduction into Heidegger's *method* in later writings, the essay *"What is Thinking?"* (1955/2006; GA11), seems an obvious place to start. We only genuinely think when we are *called into* thinking, into the practice of questioning, Heidegger argues. Thinking begins when a question puts us on a path, urging us to follow this path in a careful manner (with *Sorgfalt*), paying attention to hints (*Hinweise*) such as: consider carefully the *words* we use, notably the word *philosophy*; recollect the origin and historicity of such terms. The very word "philosophy" already opens up a path. It *is* a path, entailing a question – what *is* philosophy? – calling us into thinking. The "*what is*"-question (τι ἐστιν) already entails a particular *practice of questioning*, moreover, inaugurated by Socrates, Plato and Aristotle. As if their voice, their way of practicing philosophy, still echoes in the term, provided we pay attention to it. We are *called back* to this type of questioning. By paying attention to language, we are already underway. Our task now becomes to *respond* to the question in such a way that our question *corresponds* (*Entsprechen*) to the logos at work in this questioning practice. Philosophy means being underway as a particular kind of activity, hinted at by Aristotle's term ἐνέργεια – which literally means being-at-work, performing-a-task as human beings, namely: thinking. Being underway to thinking implies that we have to *move towards* this way of being (*entgegenkommen*), by joining a conversation.

If we try, along these lines, to come to terms with contemporary technoscience, we should first of all pay attention to the term "technoscience" itself and notice that it already reveals an important experience, namely that science has fallen under the sway of technology, as an inherently technological praxis. Rather than seeing technology as "applied science", we should see science (both experimental and theoretical science) as a practiced enforcement ("*Vollzug*") of technology (cf. Heidegger, 1944/1945/1995; GA 77, p. 6 ff.; cf. 2009 GA76, p. 125). Science is technoscience because its methodology is under the sway of technicity. Apparently contradictory tendencies, such as increased uniformity and levelling on the one hand and increased specialisation on the other, are both symptoms of technicity. Both are enforced by the power of technology, tying researchers to their specialised equipment (Heidegger, 2009 GA76, p. 124, 138, 160, p. 259), similar to how workers are tied to their specialised machines. Notwithstanding specialisation, all technologies materialise the same metaphysical claim, namely that nature must be objectified, giving rise to institutionalised forms of research organisation, be it of the pragmatic-American or of the Marxist-Russian variety (p. 269).[5]

Extrapolating these insights into the context of contemporary life sciences research, one could argue that technoscience emerges as a particular way of enframing and objectifying life and nature, namely as *bioinformation*: something which can be handled in a computational manner (sequenced, deposited, digitalised and edited via big computers). CRISPR-Cas9, for instance, could only be discovered because living (microbial) nature was already enframed as information networks, channelling and circulating data.

Heidegger's short essay is a concise version of a more extended series of reflections entitled *What is Called Thinking* (Was heißt Denken?). This lecture course, presented in 1951 and 1952 (Heidegger, 1954/2002; GA8), can perhaps be regarded as Heidegger's "discourse on method". A philosophical *way* (ὁδός) of questioning is outlined. Heidegger's aim is to *guide us* into thinking. We are called upon to *learn* the practice of thinking, paying due attention to that what summons us into thinking. We are invited to enter the road of thinking by paying attention to the questioning call: the question that is calling out to us.

These lectures again contain important methodological hints. First of all, Heidegger indicates that we learn to think *along the way*. We only learn to think by *beginning* to think, taking the road in response to the call. To find out what

---

[5] In a similar vein, Heidegger critically reviews the way science is organised by Nazism, notably the plans for building a technical university in Chiemsee: a model institute for educating the future NSDAP elite, initiated by Reichsorganisationsleiter Robert Ley, head of the German Labour Front (2009 GA76, p. 163).

"thinking" means, we cannot commence with a clear definition. Rather, we set off (off the beaten track), guided by hints that provide us with a sense of direction. We cannot build on available knowledge but have to start anew. We think we know what thinking is, but the first thing to acknowledge is our lack of understanding, as the accepted way of thinking is utterly questionable.

Another important hint is that, if we want to learn to think, we should not rely on science, especially not on cognitive psychology or neuro-science. Although science produces staggering amounts of insights into brain processes – making brain waves recordable, via acoustic amplifications, tracing their course electronically, via plotted curves, etc. (p. 17) –, such research already builds on a rather specific preconception of what thinking means. It is a research practice under the sway of technicity. Science does not think about its own way of thinking, but adopts a single-track form of thinking to engage with standardised, uniform objects (p. 58), while its technical language is replete with neologisms and acronyms. Therefore, we must question the questionable logic of technoscience and open up to other, currently precluded possibilities (cf. Glazebrook, 2012).

Another hint to guide us along the path is: pay attention to the history of the terms we use. This notably applies to our primal vocabulary: words like "thinking", "thing", "life" or "method". In close connection with this, we have to confront the thoughts of great thinkers, not by simply quoting them, but by entering into a real dialogue with them, recollecting their thoughts, but also the *unthought*, that which they did not explicitly think, but which is nonetheless audible, discernible, for those who pay attention. This questioning dialogue, *rethinking* their thoughts, entails an active attitude of confrontation (*Auseinandersetzung*). Notably, we should return to the beginning of Western thinking in ancient Greece, when thinkers for the first time responded to the questioning call, articulating their primal thoughts, albeit in a poetic and paratactic (rather than syntactic) manner. But we may also engage with thinking poets, whose sayings contain important hints as well. In order to be able to respond to the questioning call and to discern the calling question, we have to listen carefully, becoming responsive to what is calling us into thinking, so that our thinking may correspond to this call.

Although Heidegger is primarily concerned with outlining a philosophical way of thinking, he also develops (albeit in outline) a philosophical understanding of science as a *particular (and particularly questionable and obfuscating)* practice of thinking. A specific logic seems at work here, and philosophers may become the careful listeners, able to discern the questionable tenure of this logic. First of all, science has become technoscience: decisively technical. Research has fallen under the sway of technology, has evolved into a decidedly technical pursuit (compared to the sober "handiwork" of thought), evolving into a global force dominating Planet Earth. This threatening predicament is a question of thinking and language too, Heidegger maintains, for without Western logic, based on particular interpretations of words such as "thinking", "reason" and "truth", there would have been no airplanes, no atomic energy, no Enlightenment, no technoscience (p. 170).

Although *What is Called Thinking* contains promising hints for questioning contemporary technoscience, these remain provisional indications. Rather than providing us with a full-fledged, standardised and validated methodology (which would deflect from thinking), these hints urge us to develop a questioning style of thinking *along the way*, as we proceed, step by step, listening carefully to the language of science, to the way this language speaks, and induces its practitioners to speak.

Suppose that we now enter a life sciences laboratory. Would these indications allow us to find our way and put us on a track? First of all, we have to relinquish all preconceptions, realising that we *do not know* what "laboratory", "life" or "technoscience" is. Such terms merely initiate our efforts, and our pathway is bound to be a circular one (*Kreisgang*, 1935/1936/1977; GA5, p. 3), recurring again and again, although the etymological connection between "laboratory" and *work* (manual labour) may serve as a first hint. A laboratory contains many things, and laboratory entities often function as signs, as signalling measuring instruments, referring to something which is not yet there, or which is evolving in vitro. As we enter such an environment, established concepts, such as the term "instrument", should not be taken for granted. They fail to capture the-way-of-being-a-thing, the thingness of such items. In these established notions, violence is at play. By thoughtlessly using such terms, we fail to recognise that violence has already been done to the thingness of these things. All these conceptions and assertions, positioning themselves between the things and us, must be set aside, so that things can be truly encountered. Established notions must be circumvented to forego the assault (*Überfall*) on things entailed in them (1935/1936/1977; GA5, p. 10).

What is striking about laboratory entities is that they tend to be anonymous things, manufactured in a precise and uniform manner, without any visible traces of individual involvement. Precisely for that reason, an encounter seems a hazardous exercise, phenomenologically speaking, because how to engage with items which presuppose a rather elaborate, preconceived manual or script? The laboratory setting is urging us to approach such objects and instruments in very specific and preconfigured ways. Is it at all possible to take a step backwards, towards a situation where this way of approaching things was just beginning to unfold? While entering a life sciences laboratory where practices such as genome sequencing and gene editing are performed, what could serve as a moment of commencement?

Perhaps we could step back to Gregor Mendel's primal experiences during the 1860s, considering his sober formulas as the life sciences version of pre-Socratic sayings: original efforts at explicating an experience which, at that moment in time, was not yet overtaken by established technical conceptions. Mendel as a "pre-geneticist", similar to how Heraclitus is considered a "pre-Socratic". Could Mendel's monastery garden be considered a clearing, an open site in the midst of being (1935/1936/1977; GA5, p. 40), where the future objects of genetics and genomics made their appearance for the first time, were encountered for the first time in a certain manner, became accessible in a certain manner? Mendel's garden as the paradigm of life sciences experiences, the moment of commencement of an "epistemic culture" (Knorr Cetina, 2002), and Mendel's menial practice as a combination of intervention and restraint ("*Verhaltenheit*"): plotting a pathway to be re-iterated by us, in order to encounter the present?

Such a detour, I would argue, may indeed help us to further our understanding of genomics, gene editing and similar life sciences endeavours that are currently unleashed, as massive assaults on living beings, stripping them of their significance, literally *obliterating* them, replacing them by nucleic code, by *letters* (Zwart, 2016), positing operations such as replication, transcription and translation as the key processes of life (Lemmens, 2008, p. 149). Mendel introduced a particular form of literacy to refer to dominant and recessive factors (Aa, Bb, etc.), a signifying practice which subsequently evolved into computational biology: high-tech attempts to capture living beings in terms of a 4-letter alphabet (ACGT). All things we encounter in a life sciences laboratory consistently refer to this process of obliteration, which is evidently connected with biotechnology as a strive for dominance over the biosphere (Thacker, 2005). This could be a first outline of a Heideggerian interpretation of contemporary laboratory life. It would allow us to perceive laboratory practice from a sideways, oblique perspective, for rather than on proteins, nucleotides or genes, our intentionality would be focused on the way such entities are objectified and visualised, enframed and disclosed: the unquestioned enactment of pre-established conceptual repertoires. Such an exercise may help science to overcome its conceptual phobia, its "*Begriffsangst*" (Heidegger, 2009; GA 76, p. 58): the routinely obsession with data and facts, which obfuscates science's dependence on questionable but unquestioned pre-conceptions. Rather than espionage, it would entail a dialogue (*Zwiesprache*), a critical confrontation (*Auseinandersetzung*) with scientists at work in such settings.

Let this serve as a first exploration. I will now reiterate the question of method by focussing on three dimensions of technoscience: on objectified *objects* of technoscience, on the experimental *setting* of technoscience and on the global *enterprise* of technoscience.

Handling πράγματα: The Vicissitudes of Technoscientific Objects

In Heidegger's later writings, we encounter rudimentary analyses of technoscientific entities, for instance in his essay *Das Ding* (1950/2000; GA7). Technoscience, Heidegger explains, produces things like airplanes, broadcasting technologies, cinema and the like, but although these technologies seem to entail an obliteration of distance, this process will not bring the things themselves nearer to us. Quite the contrary, our sense of spatiality becomes impoverished if all distances are transfused into undefined, homogeneous space. In everyday existence, some things have retained their proximity to us, but this does not seem to apply to technoscientific artefacts.

The jug is such a thing, Heidegger argues. What is a jug? And why is it different from, say, a test-tube, or a Bresser telescope? A test-tube is a thing from which nature seems to have radically withdrawn itself. It is the exemplification of *Entzug*.

A jug is likewise a vessel created to contain emptiness, but in a different manner; but how? Although a jug is likewise a hollowness that can be filled, with wine or water for instance, it resists machination. Instead of indicating withdrawal, it draws us closer. What does science have to say about such a thing? Science can measure, in a rather precise manner, the amount of fluid a jug may contain, can define its mathematical and physical features. And test-tubes are made to make such measurements dramatically easy. A jug can likewise be measured, and its size may consciously be made to concur with a particular "measure". In the case of a jug, however, as soon as its content is measured exactly, the jug as a jug, as a meaningful entity, becomes obliterated. For now, it is only the size that counts. To address the question what kind of thing the jug really is, we have to forget about science and the metaphysical convictions concerning thingness on which it builds, and start anew. Via careful analysis, Heidegger brings to the fore that the jug is a thing which brings people together, sharing gifts of wine and water. A technoscientific (quantitative) analysis of jugs would have the opposite effect: would distance (estrange) us from the thing. And the test-tube pushes this to an extreme.

Indeed, if we extrapolate these analyses to contemporary technoscience, technoscientific things evidently diverge from poetic-artisanal entities such as jugs. Instead of assembling (bringing together), laboratory items such as microscopes, for instance, seem to *segregate*. They introduce a rupture between subject and object, between inside and outside, in vitro and in vivo, science and the public, knowledge and prejudice. A microscope will not bring microbes nearer to us, but rather creates distance: not in the physical sense, but by introducing ontological distance: between microbiologist (subject) and microbe (object). An instrument has been inserted between the two, allowing the former to zoom in and out, to objectify. Yes, a microscope provides a window into the microbial world, feigning proximity, but at the same time separating and segregating microbes and humans, ontologically speaking.

What happens when microbes are spotted through a microscope? To answer this question, Heidegger urges us to take a backward step (*Schritt zurück*), away from explanatory (i.e. technoscientific) thinking and into recollective thinking (*andenkend denken*, 1950/2000; GA7, p. 183). Techno-scientists are intentionally focussed on microbes. These living entities seem to be calling out to them, but in what manner? It is only by taking a step backwards that we may consider (from an oblique perspective) the difference between a careful handling of things like jugs and the calculative manipulation of technoscientific things like test-tubes (and the microbes that inhabit them), or PCR contrivances, or automated sequencing machines, unleashing the possibility of amplifying, sequencing, modifying and editing microbial segments of DNA.

Heidegger himself prefers to write about jugs and clogs, rather than about technical contrivances. If he speaks about the latter, he usually refers to highly complex entities, such Sputniks and atom smashers, rather than about more every-day laboratory items, such as microscopes or petri-dishes. He withdraws himself from what would amount to a comparative phenomenological analysis of life-world things versus laboratory artefacts. Meanwhile, however, laboratories have exploded, have proliferated, have become interconnected to such an extent that all the world is now becoming one gigantic lab. The global environment has been transformed into a living laboratory of terrestrial size and scale, a global web of intelligence, a noosphere. Can we still withdraw from a close analysis of technoscientific things? Sequencing machines and DNA sensors have multiplied and proliferated, while microbes and genomes (including human genomes) are being assembled, amplified, studied and manipulated virtually everywhere. Is this not crying out for a philosophical analysis along Heideggerian lines? If we see this development as worrisome, for instance, what exactly is there to worry about? Various types of discourse (bioethics, STS, ICT ethics, etc.) are already in full swing, addressing issues such as privacy, benefit sharing and risks, but is this indeed the way to genuinely question the questionability of emerging technoscience? Or is something lost or overlooked, even in these reflexive ("critical") types of discourse?

In order to address such questions, we need to analyse the situation in a careful, methodological manner. Why should Heidegger urge us to *withdraw* from such a project, opting for releasement (*Gelassenheit*) instead? The absence of an explicit explorative confrontation (*Auseinandersetzung*) with technoscience may even impoverish philosophical thinking, turning it into unworldly "quietism" (Philipse, 1998, p. 309; Blok, 2013, p. 287).

We cannot refrain from questioning technoscientific things and technoscientific practices, if only because, increasingly, they pervade the global techno-cultural ecosystem. A phenomenological analysis requires us to enter the global network of laboratories that is currently evolving precisely because we are already there. What kind of entities are objectified, datafied and studied and in what manner? What could be the threats involved? What kind of intellectual (rather than physical, chemical or biological) contamination could be entailed in such an endeavour? By asking such questions, the focus of our intentionality has already shifted from object to ambiance: to laboratories as technoscientific settings.

Laboratories as (Worldly – Unworldly) Settings

A high-tech life sciences laboratory seems an uncanny site, a *locus suspectus*, under the sway of technification, objectivation and datafication. A site which, ideally, claims to be free of contamination is actually pervaded (contaminated) by the logic of calculative thinking, the very opposite of a Heideggerian country path. Still, comparisons should not be framed in terms of "contaminated" versus "pure", for a Heideggerian approach entails the awareness that our access to the world is "always already contaminated" (Blok, 2020, p. 18), regardless of whether we opt for laboratories or forest roads. Philosophy must entail the willingness to bracket all pre-existing conceptions about things, seeing all views as "views from somewhere". A Heideggerian analysis of, say, a laboratory for microbial research, might reveal precisely *how* cutting-edge microscopy is enframing the microbial world, allowing microbes to appear to us and present themselves to us in a very particular manner (e.g. as carriers of genetic information). Rather than bringing microbes nearer to us, this type of technology may rather create distance, positing the microbe as an object (*Gegenstand*), an *adversary* even, enframing microbial nature as a reservoir for exploitation, for bioprospecting (i.e. the quest for procurable and patentable biomaterials and genes). At the same time, an act of disclosure seems at work as well. A window is created, providing access into an otherwise obfuscated realm of being. Can scientists be genuinely *addressed* by this emerging microbial world?

At first glance, Heidegger assesses technoscientific disclosure in pejorative terms. For Heidegger, technoscience is an assault on nature, as exemplified by modern quantum physics, where objects are literally obliterated, in cloud chambers ("Wilsonkammer", 1953/2000; GA7, p. 55), so that these *Gegenstände* are brought fully under technical control, seemingly deprived of all possibilities of resistance (p. 55). What such contrivances bring to the fore is a *hyper-technical interpretation* of nature. Against this backdrop, how would a Heideggerian visitor describe a microbiology or genomics lab *today*? What could be the added value of such a visit?

From a Heideggerian perspective, a life sciences laboratory emerges as an ambiguous ambiance as we have seen. On the one hand, due to technoscientific research efforts ("*Anstrengung*"), a whole dimension of nature (of being), completely ignored in day-to-day existence, is painstakingly revealed, disclosing that planet Earth is first and foremost a microbial planet. On the other hand, this microbial world is enframed in a particular manner. Rather than in microbes as such, contemporary microbiologists are probably interested in their genomes, using automated sequencing machines to identify, amplify and modify microbial and viral DNA and RNA.[6] Microbes are enframed as biomolecular machines. The moment of ἀλήθεια which may once have befallen pioneers such as Antony van Leeuwenhoek, spotting microbes for the very first time in drops of rainwater, with the help of self-made microscopes, has been obfuscated by decades of microbiological experiments, resulting in whole libraries of microbial publications and terabyte data-sets.

And yet: if we, as philosophers, feel prompted to raise the question "what kind of thing is a microbe?" – what kind of being is an *E. coli* bacterium for instance – we inevitably *need* to (visit) technoscientific laboratories, to study the kind of research that is practiced there. At the same time, via a backward step, our aim should be to move beyond this practice (and the type of questions it is addressing, the type of answers it is providing), for instance by recovering the beginning, the stupefying *Anfang*, the moment of disclosure. This may be done, for instance, by consciously engaging with Van Leeuwenhoek's careful hand-made drawings of microbes. An explorative confrontational and comparative philosophical exercise could indeed consist in comparing these impressive drawings with their technoscientific counterparts: the glossy, high-tech images produced by contemporary technoscience today, on display on PowerPoint slides at international conferences or in journals such as *Cell* or *Nature*.

---

[6] Heidegger mentions viral research as an instance of switching ("*Umschaltung*") from biology to bio-chemistry, and nowadays, one could argue, we notice a similar switching, even more radical perhaps, towards computational bio-informatics (2009; GA76, p. 128).

Why did Heidegger not engage in this type of research himself? What was the ground of his reluctance? Would philosophical questioning, as a critical practice, be fostered or endangered by taking such an "empirical turn"? Rather than spying on researchers from a social science perspective, peering at them through a key hole as it were, philosophers should engage in a dialogue with practitioners, from a position of close proximity or *Nachbarschaft*. While empirical social sciences enframe microbiologists themselves as objects or adversaries, philosophical conversations offer a common pathway, a *Feldweg-Gespräch* (Heidegger, 1944/1945/1995; GA77), where philosophical questions concerning technoscience are explored in dialogue. Or should scientists consider engagement with philosophy as a contamination of their research and vice versa?

What makes a Heideggerian consideration of laboratories even more urgent is the awareness that it has become impossible to regard them as secluded, insulated sites. They proliferated to such an extent that the socio-economic environment has evolved into a global laboratory for producing and circulating bio-data on a massive scale. Not only in the sense that our global environment is pervaded by technical contrivances such as radios, earplugs and cell phones (Babich, 2018; Fidalgo, 2009) but also in the sense that virtually all societal settings have become "living laboratories" for experimental research. We are all research subjects now and our behavioural repertoires are monitored quite closely, including our click-behaviour as digital consumers. *All* the available information is analysed, everything is relevant, however trivial it may seem (Zwart, 2016). Rather than being secluded, protected sites, laboratories have expanded to encompass *everything*. The basic topology of the laboratory has changed from an unworldly setting into a collective ambiance of intelligence (νοῦς).

Heidegger was quite right when he suggested cybernetics as the new paradigm of technoscientific research, more optimally poised to understand our global world than philosophy itself (Lemmens, 2008; Nugent, 2014; Zwier & Blok, 2019). In a cybernetic global environment, human beings are enframed as information devices (producing, processing and analysing information continuously). Cybernetics is the universal science, while philosophy is becoming irrelevant (1959/2017; GA89). Studying human behaviour via feedback mechanisms makes humans transparent, even though, precisely as *thinking beings*, open to the call of Being, they are effectively *obliterated*. Heidegger is not criticising cybernetics as a performative science. What is questioned is cybernetics as a metaphysics, i.e. as an answer to the question what human beings really *are* ("information devices"). Cybernetically speaking, the world is evolving into a global web-like device for procuring, processing, circulating and validating information. This is what all beings have in common, microbes as well as humans: they are circuits of information. The task of philosophy would be to explicate this metaphysical claim, so that we may withdraw from it (*Entzug*) and remain open to other possible interpretations. Rather than being "seized" by the dictates of information gathering, philosophy assesses how informatics / cybernetics is reframing our world-picture and mobilising humanity on a global scale.

This also allows us to position a Heideggerian phenomenological method vis-à-vis sociological, anthropological and ethnographical approaches, often referred to as STS. On the one hand, we notice convergence. Heidegger's emphasis on the technicity of technoscience already offers a bridge (Hottois, 1984; Lemmens, 2008; Kastenhofer & Schwarz, 2011). Moreover, from a Heideggerian perspective, technoscientific contrivances (such as microscopes) give rise to objectification, bringing microbes closer to us, literally into view, while at the same time segregating scientists as subjects (the scientific gaze) from their objects (microbes; cf. Zwart, 2020). But such contrivances also serve as "inscription devices" (Latour & Woolgar, 1986), literally *obliterating* the object, as we have seen, replacing material entities with symbols, measurements and codes that can be quantitatively, stochastically and digitally handled. Such a practice of epistemological questioning ("Begriffsarbeit") addresses tangible entities and fosters reflection on concrete practices, instead of articulating such issues in abstract philosophical terms, in fear of contamination (Knorr Cetina, 2002; Rheinberger, 2006; Stahl, 2018, p. 10). Still, for Heidegger, philosophy will never mean studying "daily practices" of "research cultures" (Lynch, 1985; Knorr Cetina, 2002) from a sociological, anthropological or ethnographical (third person) perspective. Rather, thinking for him means: questioning the grounding ontological convictions at work, the ways-of-being of technoscientific artefacts, via confrontational dialogue ("Auseinandersetzung"). Still, although Heideggerian ontology and STS reflect radically different attitudes, they inevitably encounter one another (underway to the laboratories of technoscience) and may therefore mutually inspire and challenge (or irritate) one another.

Technoscience as a Global Research Enterprise

Another pivotal text, *The age of the world-picture* (Heidegger, 1938/1977; GA5), likewise addresses objectification and obliteration of technoscientific objects, while calling attention to technoscience as a global endeavour. Technoscience enforces phenomena to come forward via objectification (*Vergegenständlichung*). According to Heidegger, science is basically *research* (*Forschung*; 1938/1977; GA5, p. 79; cf. 2009; GA 76, p. 123), i.e. technoscience: grounded in technology. Its methodologies are procedures for establishing and securing claims by enhancing validity, objectivity and replicability. Technoscience no longer calls for erudition (scholarship, *Gelehrsamkeit*), but rather entails a painstakingly planned and institutionalised practice. Although science discovery may commence as small-scale, careful, creative, and menial research practices, – conducted by pioneers such as Gregor Mendel or Rosalind Franklin for instance (Zwart, 2016) –, Heidegger discerns an inherent force at work in technoscience, pushing it towards developing into a large-scale, anonymous enterprise (*Betrieb*) whose objective is the objectification of nature: an enterprise on an *industrial* scale, even when performed on university campuses, where the difference between classical and technical universities evaporated. Research equipment is industrially produced and this includes the assembly line production of cell cultures and research animals (e.g. nude mice or Wistar rats) as technoscientific commodities (cf. Rader, 2004). Research is designed in a rigorous manner and this design (*Entwurf*) determines how research unfolds in particular fields. Science as research is conducted in accordance with rigorous methodological procedures (1938/1977; GA5, p. 79) in such a way that optimal conditions are created to ensure that research phenomena can be *secured* in an exact, uniform, predictable and replicable manner. This is exemplified by experimental practice, aimed at securing the precedence of the methodological *procedure* over the entities that are studied. Indeed, the methodological procedure determines and secures how these entities ("objects") are allowed to appear. Ultimately, the objective of science is to ensure that more research can be done in the future (technoscience as a self-serving industry). In short, what is driving scientific research is the need to secure and expand the enterprise of technoscience itself. Building on previous results, new projects must continuously be forged. This is what defines the *modus operandi* of scientific research (Rouse, 2005), supporting the incessant demands of the research enterprise by supplying new problems to work on, and new materials and institutional resources to work on them.

Heidegger's diagnostic is exemplified quite tellingly by contemporary life sciences research, for instance by genomics in its multiple -omics varieties and branches. Genomics is a particular way of securing and objectifying living entities, namely as bio-information, so that they can be sequenced and studied in a replicable manner, preferably symbolically, on computer screens (Thacker, 2005). In the course of the twentieth century, Mendelian genetics (initially a handicraft, building on artisanal practices of plant cultivation) evolved into molecular and computational biology, interpreting life in terms of data, on the basis of the ontological conviction that life essentially *is* information (Venter, 2013). Living beings are literally obliterated, replaced by letters (symbols, digital code), by terabytes of data litter. Genomics has evolved into a (technologically enhanced) global arena of planned research: a global research enterprise ("big science"). Automated sequencing machines enframe *all* living beings as carriers and circuits of information. This conveys a metaphysical claim, namely that *all is one*: all life is information. Indeed, the basic metaphysical claim grounding the life sciences in general and genomics in particular echoes Heraclitus' saying that "all is one" (ἓν πάντα εἶναι), for the claim that is made, is that all life (or even: *everything there is*) is information (1951/2000; GA7). This fundamental interpretation, this *Begriff* or *Inbegriff* ("encompassing claim": 2009; GA76, p. 77) is the conceptual ground which allows this type of research to unfold, relentlessly marginalising, eliminating or transforming all other ways of studying living nature (so that, in the genomics era, ecology for instance becomes bio-prospecting). Even philosophical and ethical reflection becomes planned research, embedded in big science research programs: philosophers as specialists, addressing specific normative questions.

Nature is made calculable, is determined in terms of calculability. Heidegger himself uses elementary particle physics as his pet example (the smashing of atoms by big machines), but genomics has often been compared to "splitting" the atom: the equivalent of high energy physics in the realm of life sciences research (Zwart, 2008, p. 375), where research outputs are generated, validated and communicated continuously. This technoscientific interpretation of *all* living beings, of *everything* (πάντα) as information must be overcome by taking a step backwards. By recollecting Heraclitus's saying that all is one (1951/2000; GA7), we realise that the metaphysical claim at work in contemporary technoscience is *one particular* interpretation of what beings are, obfuscating other possible interpretations: other (less calculative and technological, more poetic) ways of standing out towards things we encounter. Indeed, the "relevance" of philosophy, as patient thinking, resides in a philosophical questioning of the metaphysical claim that is steering data-focussed life sciences research, thereby preparing the ground for a new beginning ("*andere Anfang*").

Genomics not only obliterates living beings (replacing them by digital code, assembled in data repositories) but also marginalises the work of the scientists themselves, relying increasingly on automation. The enterprising character of modern science affects its practitioners as well. On the side of the researcher (the subject-pole), genomics likewise entails erosion (*Aushöhlung der forschenden Arbeit*) of research work via automation (Heidegger, 1938/1977; GA5, p. 97). Research requires constant activity, performativity and effectiveness rather than insight, although the actual work is outsourced to machines. Genomics is big science,[7] representing the emergence of gigantism (*das Riesenhafte*) in life sciences research, even though, as Heidegger points out, the gigantic (big machinery) has the paradoxical tendency to focus on the increasingly small (p. 95), on elementary constituents of life (genes, nucleotides, amino acids, etc.). The gigantic makes nature computationable.

This does not mean that philosophers should retreat into mere erudition ("die Romantik des Gelehrtentums", 1938/1977; GA5, p. 85; cf. 2009; GA 76, p. 113). They should be involved in this development, albeit in such a way that they are not completely seized by it. From a position of close proximity, philosophers may question, for instance, how quantification (i.e. making nature computational) has evolved into a very specific *form* of quantification, namely datafication, reflecting the metaphysical claim, already pointed out above, that *everything is* information. Genomics sequences, assembled in digital databases, exemplify what Heidegger refers to as "the endlessly extended emptiness of the purely quantitative" ("die endlos zerdehnte Leere des nur Quantitativen", p. 95). At the same time, however, the quantifiable is always surrounded by a remainder, something which remains unquantifiable, so that datafication (as a specific form of objectification) inevitably casts a non-representable shadow of unquantifiability (p. 95): a refuse which refuses computation.

We cannot negate the current computational trend by withdrawing into mere erudition or by trying to oppose it (protesting against datafication and the reduction of life to information) as this would merely confirm the marginalisation of reflection. Rather, the Heideggerian option would be to question the interpretation of being as information (and of truth as algorithmic validation) by taking a step backwards, preparing the ground for an exodus ("*Auswanderung*") out of this erosion of human experience (Heidegger, 2009; GA76, p. 100), providing an alternative for the

---

[7] From a European perspective, genomics may be seen as "Americanism" (p. 112). By this we actually mean, Heidegger argues, that biology became an enterprise (big science).

obliteration of nature at the object-pole of the knowledge-production process. How? By paying attention to the words we use, by stepping backwards, towards moments of commencement, acknowledging that genomics entails a particular interpretation of being and truth. It is not a mere technology in the instrumental sense ("applied research"), but a particular way of securing and understanding being (as information) and a particular way of securing and understanding truth (as algorithmic validation and replication). Genomics is a global research enterprise, aiming to secure and enhance a particular way of proceeding. What makes research-as-enterprise important, is not the intrinsic significance of its discoveries, but the possibility of ensuring sufficient options for further research in terms of research programs, funding opportunities, lab facilities, and so on. Technoscience expands its domain of research by making entities computable.

Concluding Reflection: Is a Technoscience-Philosophy Dialogue Possible?

The later Heidegger seems pessimistic concerning the possibility of a genuine science – philosophy confrontation ("*Auseinandersetzung*"), not because they stand too far apart, but because they are so decidedly interlinked with each other, from the very beginning, that both seem unable, on their own initiative, to prepare the ground for such a conversation (Heidegger, 2009; GA 76; p. 273). Moreover, there is no pathway leading from science to reflection. Therefore, the only option is to begin with a philosophical questioning of the *way of being* of the entities produced, studied and obliterated by technoscience, from a sideways perspective, going beyond the positive sciences themselves, posing questions they methodically exclude (Mazijk, 2019, p. 539). This is difficult, but not impossible, Heidegger maintains. Science has to remain informed about the *way of being* of the entities it studies, while metaphysics (having been assigned the question concerning the way of being of beings) must pay due attention to how these beings are actually made accessible and disclosed by science. Therefore, metaphysics and science both have an interest in addressing the question of the being of these beings, together ("*einträchtig*": Heidegger, 2009; GA 76; pp. 276–277).[8] The being of beings manifests itself in multiple ways, as Aristoteles said (τό öν λέγεται πολλαχώς), and this inevitably raises the question concerning the way of being of neo-things, brought to the fore by technoscience (2009; GA 76; p. 279). In this questioning practice resides philosophy's "relevance".

[8] "Die Wissenschaft, die das Seiende erforscht, liegt daran, über das Sein des Seienden unterrichtet zu bleiben… Der Metaphysik andrerseits [ist] die Frage nach dem Sein des Seienden zugewiesen, wobei sie gebührend darauf achten wird, in welcher Gestalt ihr das Seiende durch die Wissenschaft zugänglich gemacht wird. Metaphysik und Wissenschaft finden sich somit in der Frage nach dem Sein des Seienden einträchtig zusammen" (2009; GA 76; pp. 276–277).

At the "subject-pole" of the knowledge production process, research becomes a technical endeavour, carried out by machines: an industrialised praxis, computer-based labour, following procedures and protocols attuned to the technicity of technoscience. At the "object-pole", natural entities are likewise enframed in a technical manner. Living beings become molecular machines, guided by bio-molecular programs. As molecular biologist Max Delbrück (1971) argued, molecular biology echoes Aristotelean ideas, albeit in a technicised manner, for while molecules are the "matter", DNA constitutes the program: the *form* (εἶδος) or *formula* (λόγος) of living things (Zwart, 2017, 2019). Genomics replaces the static (deterministic) logic of traditional genetics by an ontology of *becoming* (Rouse, 2005). What is revealed and what is obfuscated in such an enframing of living beings, − which actually represents the completion of Western metaphysics (Heidegger 2009; GA 76; p. 294)? That is the type of question philosophy should ask. Not in an abstract manner, but by paying close attention to the language, practice and technicity of technoscience, so as to discern and question the guiding metaphysical claim at work in contemporary technoscience ("everything is information").

References

Babich, B. (2018). Between Heidegger and Adorno: Airplanes, radios, and Sloterdijks' atmoterrorism. *Kronos: Philosophical Journal, 6*, 133–158.

Blok, V. (2013). Towards the rehabilitation of the will in contemporary philosophy. *Journal of the British Society for Phenomenology, 44*(3), 286–301.

Blok, V. (2015). Heidegger and Derrida on the nature of questioning: Towards the rehabilitation of questioning in contemporary philosophy. *Journal of the British Society for Phenomenology, 46*(4), 307–322. https://doi.org/10.1080/00071773.2015.1052659

Blok, V. (2020). *Heidegger's concept of philosophical method: Innovating philosophy in the age of global warming*. Routledge.

Dahlstrom, D. (1994). Heidegger's method: Philosophical concepts as formal indications. *The Review of Metaphysics, 47*(4), 775–795.

Delbrück, M. (1971). Aristotle-totle-totle. In J. Monod & E. Borek (Eds.), *Of microbes and life* (pp. 50–55). Columbia University Press.

Fidalgo, A. (2009). Heidegger's cell phone – Ubiquitous communication and existential distance. *Revista MATRIZes, 3*(1), 1–20.

Gadamer, H.-G. (1990). *Wahrheit und Methode: Grundzüge einer philosophischen Hermeneutik*. Mohr.

Glazebrook, T. (2000). *Heidegger's philosophy of science*. Fordham University Press.

Glazebrook, T. (2012). *Why read Heidegger on science?* SUNY Press.

Hadjioannou, C. (2019). Heidegger's critique of techno-science as a critique of Husserl's Reductive Method. In A. Wendland, C. Merwin, & C. Hadjioannou (Eds.), *Heidegger on technology* (pp. 57–73). Routledge.

Heidegger, M. (1920/1921/1995). Gesamtausgabe. II. Abteilung: Vorlesungen 1919-1944. Band 60: *Phänomenologie des religiösen Lebens*. Frankfurt am Main: Vittorio Klostermann (GA60).

Heidegger, M. (1927/1977). Gesamtausgabe. I. Abteilung: Veröffentlichte Schriften 1914-1970. Band 2: *Sein und Zeit*. Frankfurt am Main: Vittorio Klostermann (GA2).

Heidegger, M. (1927/1975). Gesamtausgabe. II. Abteilung: Vorlesungen 1923-1944. Band 24: *Die Grundprobleme der Phänomenologie*. Frankfurt am Main: Vittorio Klostermann (GA24).

Heidegger, M. (1935/1936/1977). Der Ursprung des Kunstwerkes. In Gesamtausgabe. I. Abteilung: Veröffentlichte Schriften 1914-1970. Band 5: *Holzwege* (pp. 1–74). Frankfurt am Main: Vittorio Klostermann (GA5).
Heidegger, M. (1938/1977). Der Ursprung des Kunstwerkes. In Gesamtausgabe. I. Abteilung: Veröffentlichte Schriften 1914-1970. Band 5: *Holzwege* (pp. 75–114). Frankfurt am Main: Vittorio Klostermann (GA5).
Heidegger, M. (1944/1945/1995). Gesamtausgabe. III. Abteilung: Unveröffentlichte Abhandlungen, Vorträge – Gedachtes. Band 77: *Feldweg-Gespräche*. Frankfurt am Main: Vittorio Klostermann (GA77).
Heidegger, M. (1946/1977). Wozu Dichter?. In Gesamtausgabe. I. Abteilung: Veröffentlichte Schriften 1914-1970. Band 5: *Holzwege* (pp. 269–320). Frankfurt am Main: Vittorio Klostermann (GA5).
Heidegger, M. (1950/2000). Das Ding. In Gesamtausgabe. I. Abteilung: Veröffentlichte Schriften 1914-1970. Band 7: *Vorträge und Aufsätze* (pp. 165–188). Frankfurt am Main: Vittorio Klostermann (GA7).
Heidegger, M. (1951/2000). Logos (Heraklit, Fragment 50). In Gesamtausgabe. I. Abteilung: Veröffentlichte Schriften 1914-1970. Band 7: *Vorträge und Aufsätze* (pp. 211–234). Frankfurt am Main: Vittorio Klostermann (GA7).
Heidegger, M. (1953/2000). Wissenschaft und Besinnung. In Gesamtausgabe. I. Abteilung: Veröffentlichte Schriften 1914-1970. Band 7: *Vorträge und Aufsätze* (pp. 37–66). Frankfurt am Main: Vittorio Klostermann (GA7).
Heidegger, M. (1954/2002). Gesamtausgabe. I. Abteilung: Veröffentlichte Schriften 1910-1976. Band 8: *Was heißt denken?* Frankfurt am Main: Vittorio Klostermann (GA8).
Heidegger, M. (1955/2006). *Was ist das – die Philosophie?* In Gesamtausgabe. I. Abteilung: Veröffentlichte Schriften 1910-1976. Band 11: *Identität und Differenz* (pp. 3–26). Frankfurt am Main: Vittorio Klostermann (GA11).
Heidegger, M. (1959/1985). Gesamtausgabe. I. Abteilung: Veröffentlichte Schriften 1910-1976. Band 12: Unterwegs zur Sprache. Frankfurt am Main: Vittorio Klostermann (GA12).
Heidegger, M. (1959/2017). Gesamtausgabe. IV. Abteilung: Hinweise und Aufzeichnungen. Band 89: Zollikoner Seminare. Frankfurt am Main: Vittorio Klostermann (GA89).
Heidegger, M. (2009). Gesamtausgabe. III. Abteilung: Unveröffentlichte Abhandlungen, Vorträge – Gedachtes. Band 76: Leitgedanken zur Entstehung der Metaphysik, der neuzeitlichen Wissenschaft und modernen Technik. Frankfurt am Main: Vittorio Klostermann (GA76).
Hottois, G. (1984). *Le signe et la technique: la philosophie à l'épreuve de la technique*. Aubier.
Ihde, D. (2011). Husserl's Galileo needed a telescope. *Philosophy and Technology, 24*(1), 69–82.
Kastenhofer, K., & Schwarz, A. (2011). Probing technoscience. *Poiesis and Praxis, 8*(2–3), 61–65. https://doi.org/10.1007/s10202-011-0103-0
Knorr Cetina, K. (2002). *Wissenskulturen: ein Vergleich naturwissenschaftlicher Wissensformen*. Suhrkamp.
Kockelmans, J. (1985). *Heidegger and science*. Centre for Advanced Research in Phenomenology: University Press of America.
Latour, B., & Woolgar, S. (1986). *Laboratory life: The construction of scientific facts*. Princeton University Press.
Lemmens, P. (2008). *Gedreven door techniek: de menselijke conditie en de biotechnologische revolutie*. BoxPress/Radboud University.
Lynch, M. (1985). *Art and artefact in laboratory science: Study of shop work and shop talk in a research laboratory*. Routledge & Kegan Paul.
Lynch, P. (2006). *The emergence of numerical weather prediction: Richardson's ream*. Cambridge University Press.
Musil, R. (1930/1978). *Der Mann ohne Eigenschaften I*. Rowohlt.
Nugent, P. (2014). *Rethinking Heidegger's framing of cybernetics: Toward a theory of phenomenal appreciation*. In IEEE conference Norbert Wiener in the 21st century. https://doi.org/10.1109/NORBERT.2014.6893916.

Owens, W. (1987). Heidegger and the philosophy of language. *Auslegung: A Journal of Philosophy, 14*(1), 49–66.
Philipse, H. (1998). *Heidegger's philosophy of being. A critical interpretation*. Princeton University Press.
Rader, K. (2004). *Making mice: Standardizing animals for American biomedical research, 1900–1955*. Princeton University Press.
Rheinberger, H.–. J. (2006). *Epistemologie des Konkreten: Studien zur Geschichte der modernen Biologie*. Suhrkamp.
Richardson. (1922/2007). *Weather prediction by numerical process*. Cambridge Mathematical Library.
Rouse, J. (2005). *Heidegger on science and naturalism*. Division/Faculty Publications 36. https://wesscholar.wesleyan.edu/div1facpubs/36
Shockey, R. M. (2010). Formal Indication? Heidegger's Method in Sein und Zeit. *Inquiry: An Interdisciplinary Journal of Philosophy, 53*(6), 525–553.
Stahl, L. M. (2018). *Isolieren – Zerlegen – Stillstellen: Zum Verhältnis von Bios und Biologie am Beispiel mikroskopischer Bildgebung*. Wilhelm Fink.
Streeter, R. (1997). Heidegger's formal indication: A question of method in *being and time*. *Man and World, 30*, 413–430.
Thacker, E. (2005). *The global genome: Biotechnology, politics and culture*. MIT Press.
Thomson, I. (1999). *The end of onto-theology: Understanding Heidegger's turn, method, and politics* (Thesis). San Diego: University of California.
van Mazijk, C. (2019). Heidegger and Husserl on the technological-scientific worldview. *Human Studies, 42*, 519–541. https://doi.org/10.1007/s10746-019-09526-2
Venter, J. C. (2013). *Life at the speed of light: From the double helix to the dawn of digital life*. Viking.
von Herrmann, F.-W. (1990). *Weg und Methode: Zur hermeneutischen Phänomenologie des seinsgeschichtlichen Denkens*. Klostermann.
Weibel, P. (2009). Sloterdijk und die Methode der Definition. In M. Jongen, S. van Tuinen, & K. Hemelsoet (Eds.), *Die Vermessung des Ungeheuren: Philosophie nach Peter Sloterdijk* (pp. 42–55). Fink.
Wendland, A., Merwin, C., & Hadjioannou, C. (Eds.). (2019). *Heidegger on technology*. Routledge.
Wilde, N. (2020). Moods and meteors: A reconstruction of Heidegger's atmospherology. *Human Studies*. https://doi.org/10.1007/s10746-020-09541-8
Zwart, H. (2008). Understanding the human genome project: A biographical approach. *New Genetics & Society, 27*(4), 353–376.
Zwart, H. (2016). The obliteration of life: Depersonalization and disembodiment in the terabyte era. *New Genetics and Society, 35*(1), 69–89. https://doi.org/10.1080/14636778.2016.1143770
Zwart, H. (2017). The oblique perspective: Philosophical diagnostics of contemporary life sciences research. *Life Sciences, Society & Policy, 13*, 4. https://doi.org/10.1186/s40504-017-0047-9
Zwart, H. (2019). What is mimicked by biomimicry? Synthetic cells as exemplifications of the three-fold biomimicry paradox. *Environmental Values, 28*(5), 527–549. https://doi.org/10.3197/096327119X15579936382356
Zwart, H. (2020). Iconoclasm and imagination: Gaston Bachelard's philosophy of technoscience. *Human Studies, 43*, 61–87. https://doi.org/10.1007/s10746-019-09529-z
Zwier, J., & Blok, V. (2019). Seeing through the fumes: Technology and asymmetry in the Anthropocene. *Human Studies, 42*, 621–646. https://doi.org/10.1007/s10746-019-09508-4

Chapter 7
Pierre Teilhard de Chardin's Phenomenology of the Noosphere

Introduction

Although Pierre Teilhard de Chardin (1881–1955) was thoroughly trained in philosophy and theology, he was first and foremost a paleoanthropologist, directly involved in the discovery of *Homo erectus pekinensis* ("Sinanthropus") in China in the 1920s and 1930s. He came from a Catholic aristocratic background, was ordained a priest in 1911, survived World War I (as a stretcher-bearer, distinguished with the Legion of Honour), joined the Jesuit Order, conducted paleoanthropological field work during the interbellum, and became entangled in a conflict with his Jesuit superiors (over pantheism and the concept of original sin) until his death in New York (in exile more or less).[1] When his writings were published (shortly after his death, as his superiors forbade publication during his lifetime), he quickly became an intellectual celebrity. Currently, he is credited with having anticipated Gaia theory (King, 2006), the global village concept (McLuhan, 1962), the Internet (Barlow, 1992; Cobb, 1998), the WWW (Garreau, 2005, p. 256; Greenfield, 2014, p. 9), transhumanism (Delio, 2014; Steinhart, 2008), the "global brain" (Stock, 1993), and the Anthropocene (e.g. Crutzen, 2002; Steffen et al., 2011).

While conducting palaeontological research in the Ordos desert, he conceived a vision of cosmic evolution, with anthropogenesis as a crucial moment (Delio, 2014, p. 2; Skehan, 2006, p. 23). For Teilhard, scientific research was a religious activity: a priestly practice, a spiritual exercise, an *Opus Dei* (Udías, 2009). Books such as *The Human Phenomenon* and *The Divine Milieu* foster convergence between evolutionary research and religious faith. His core concept (his *philosopheme*) is the "noosphere" (derived from νοῦς: i.e. "mind" or "intellect"), co-developed with biogeochemist Vladimir Vernadsky and referring to the evolving layer of language and communication, science and technology, information and communication,

[1] Positive views on Teilhard's work voiced by both Pope Benedict XVI and Pope Francis may signal that the "monitum" (formal warning) concerning his work will be withdrawn.

H. Zwart, *Continental Philosophy of Technoscience*, Philosophy of Engineering and Technology 38, https://doi.org/10.1007/978-3-030-84570-4_7

transforming and absorbing both the geosphere and the biosphere, emerging and proliferating *via us*. Although humans should not consider themselves the centre of the universe, by modifying life and creating neo-life, we are uniquely positioned along the axis of evolution, envisioned by Teilhard as an increasingly self-conscious and self-directing process (1955/2015, p. 3), spiralling towards an endpoint, thematised by Teilhard as the *Omega point*, comparable to Hegel's idea of absolute knowing (as will be discussed below).

Teilhard spent many years abroad, in Egypt, China and the United States, and was deeply fascinated by Cro-Magnon parietal art. For Teilhard, cave art represents a turning point in the process of noogenesis (the birth of thinking, the emergence of self-consciousness). He was a close friend of French archaeologist Abbé Henri Breuil (1877–1961), professor at the *Collège de France* from 1929 to 1947, with whom he visited parietal sites like Lascaux and Mas d'Azil (Aczel, 2007, p. 51). Besides being astonishing works of art, these paintings reflect a spiritual (symbolic) dimension. Drawings of animals are accompanied by signs, dots and pairs of lines and often seem superimposed on one another, like playing cards. All this suggests that, rather than being representations, the paintings functioned as symbols or pictograms in shamanistic rituals, to probe and influence the movements of herds. Censorship prevented him from publishing his major writings during his lifetime, but after copies of manuscripts had been circulating for years, books such as *The Human Phenomenon* and *The Divine Milieu* were published immediately after his death in 1955, leading to world-wide fame.

Teilhard sees the ancient, Alexandrian Cosmos as an "imaginary world" (Teilhard de Chardin, 1959, p. 25; Teilhard de Chardin, 1965, p. 238) and modern technoscience as a moment of awakening. Technophobic resistance towards technological progress reflects the extent to which technoscience entails a rupture with the "poetry" of a traditional, agricultural world. Technoscience invokes unease because it entails a dethronement of the narcissistic ego (Teilhard de Chardin, 1959, p. 245). The techno-scientific world is so large that humans become trivialised (Teilhard de Chardin, 1957). At the same time, there is something unique about humans, because the noosphere (the evolving layer of language and communication, science and technology) emerges and proliferates via us.

What Is Phenomenology?

Teilhard's oeuvre will be presented in this chapter as a "phenomenology of technoscience", albeit in a particular sense. Defining phenomenology "point-blank" is notoriously difficult (Spiegelberg, 1965, p. 1) and although both Bachelard and Heidegger can be considered as phenomenologists, they are not phenomenologists in the prototypical (say, Husserlian) sense. In the previous chapter, instead of defining phenomenology, we introduced it as a philosophical approach, a method in the genuine sense, as something which is developed *along the way*. And not by one authoritative author, but by multiple authors, by a "philosophical movement" (Spiegelberg, 1965).

According to the *Stanford Encyclopaedia of Philosophy* (Smith, 2018), phenomenology is the study of the way we experience things, the way in which things appear to consciousness. Phenomenology studies the structures of consciousness from a first-person viewpoint. The core structure of consciousness is intentionality, i.e. the experience that the conscious mind is not a passive recipient of information, but *directed towards* something and *interacting with* something: the object of experience. Like Bachelard and Heidegger, Pierre Teilhard de Chardin is a phenomenologist, but not in the strict (Husserlian) sense. He studies consciousness from a historical and dialectical perspective. His version of phenomenology (as developed notably in *The Human Phenomenon*) comes close to how Hegel understood the term in his *Phenomenology of the Spirit*. Indeed, while Husserlian (esoteric) phenomenologists never considered Hegel as part of the phenomenological movement, French (exoteric) phenomenology took his inclusion for granted (Spiegelberg, 1965, p. 12). Teilhard de Chardin's oeuvre is phenomenological in the dialectical sense of the term, presenting a radical extension of the dialectical-phenomenological view compared to Hegel. While Hegel's phenomenology presents the drama of the genesis of science ("*das Werden der Wissenschaft*"), starting with empiricism and tracing the ascent of self-consciousness up to its fulfilment (i.e. absolute knowing), Teilhard broadens the scope quite drastically, seeing human evolution (anthropogenesis) in the context of evolution as such, against a dramatically extended temporal horizon.

Hegel conceives phenomenology as the study of the historical morphology of the spirit, tracing its long procession through various stages, as revealed and preserved in various *externalisations*, whose remnants constitute the *Schädelstätte* (the skull site) of consciousness (Hegel, 1807/1986, p. 591). It is precisely – *literally* – in this sense that Teilhard's phenomenology is a phenomenology of the spirit, using paleo-anthropological skull research as point of departure for studying the vicissitudes of the spirit on its way to absolute knowing, the Omega point.

For Teilhard, being means being in flux, in process, and evolution applies not only to living beings, but to *being as such*, so that even molecules and stars evolve, although Teilhard's focus as a phenomenologist is on the emergence and dialectical evolution of consciousness (Grim & Tucker, 2006, p. 56). Again, however, consciousness is seen as an integral dimension of being: from primal cellular consciousness via human self-consciousness (i.e. the co-evolution of consciousness, tool-use and language) up the emergence of a global noosphere (the global web of technology, intelligence and information, resulting in hyper-consciousness). Human consciousness, or being-in-the world, is not considered as an a priori given, but as the outcome of a process of becoming, and paleo-anthropology studies a crucial stage of this process, from the birth of humanity up to the daybreak of reflection, twenty-five centuries ago (the *Achsenzeit*, which Hegel uses as his starting-point). The human condition ("*Dasein*", being-in-the-world) is an *outcome*: the *result* of a long history of hominization, in which language and tool-use play a crucial role (cf.

Sloterdijk, 2001, p. 153), reflected in the development of the human skull (as the object of choice of paleo-anthropological inquiry).

Thus, for Teilhard, consciousness is studied from multiple perspectives, combining an interior (first-person) perspective with an external perspective, informed by scientific (e.g. geological, biological and paleo-anthropological) research, and enriching traditional phenomenology with a diachronic (historical and evolutionary) viewpoint. For Teilhard, the challenge of contemporary thinking is to broaden the scope of philosophical reflection. For many philosophers, the scope of historical consciousness is still defined by the dawn of Western thinking in ancient Greece, twenty-five centuries ago. Teilhard adopts a much deeper historical scale, so as to endeavour a radical broadening of the temporal horizon of human self-reflection, thereby transcending the egocentric, anthropocentric and Eurocentric constraints of classical (Husserlian) phenomenology.

Teilhard de Chardin's Views on Science, Technology and Evolution

Teilhard's magnum opus *The Human Phenomenon* (1955/2015) was completed in China in 1940 and published posthumously. Here and elsewhere Teilhard argues that a direction, an orientation, an axis is discernible in evolution, namely towards increasing complexity and interiority (p. 8), towards integration and sublimation (p. 180), towards self-consciousness and self-directedness. Teilhard sees life as a spiralling process of becoming or "sublimation" (p. 120), while human beings represent the moment in time when evolution becomes "conscious of itself" and consciously self-directed (p. 20, p. 126). Via technoscience, humans are able to drastically reorganise the conditions of their own evolutionary development on an unprecedented scale. This has brought us on the verge of a crucial moment in the history of life, Teilhard claims, as humanity has entered an era of planetisation. Dialectically speaking, current humanity represents the final transition from a more or less implicit awareness of the mechanisms of evolution in animals and other life forms (M_1), via a self-conscious manipulative understanding of these mechanisms (putting them to work on behalf of anthropocentric self-interest: M_2), up to assuming full responsibility over the future course of evolution as such, thereby radically sublating the boundaries between the "natural" and the "artificial" (M_3), giving rise to synthetic hybridisation.

What is disconcerting about the human phenomenon, Teilhard argues, is that scientific portrayals (anatomical, physiological, neurological, genetic, etc.) consistently fall short. They lack a key dimension. Humans are animals, but they also represent a leap, a discontinuity, a metamorphosis, a crisis, a spiritual awakening. Via humans, the *noosphere* (the "layer of thinking", i.e. the global network of science, technology and information) increasingly absorbs and transforms the geosphere and the biosphere. A turn of profound importance is taking place in the world as we are entering a new era. Via us, evolution has begun to actively redirect itself. Through humans, a techno-cultural world is born, an altogether different form of life. Contrary to anthropocentrism, however, Teilhard emphasises that this is not brought about *by* human beings. Rather, Teilhard points to the presence of something greater than ourselves: the spirit, moving forward *within* us, *drawing* us towards this future, via culture and technology as augmented forms of consciousness and transmissible reflection.

The Human Phenomenon depicts a dramatic, panoramic vision of the evolving cosmos, the process of cosmogenesis, beginning at the atomic and molecular levels, where the stuff of the universe continuously degrades and pulverises (under the sway of entropy), while at the same time giving rise to more and more organised forms of matter, via synthesis and complexification. Stars and planets are basically laboratories for producing atoms and molecules, where matter evolves in the direction of larger molecules (1955/2015, p. 19). On planet Earth, geological research reveals the formation of larger crystal molecules and polymers. In the course of evolution, Teilhard argues, an interior, psychic dimension of things increasingly manifests itself. Planet Earth is a polymerising world (p. 36), giving rise to phenomena of life, to increased interiority and cellular awakening, culminating in the dawn of consciousness (psychogenesis). Indeed, for Teilhard, the phenomenology of consciousness begins with the cellular revolution: the leap from pre-consciousness in prelife to the rudimentary consciousness of prokaryotic single cells as living beings up to multi-cellular organisms and mammals. Cellular awakening is the first transformation in the emergence of consciousness.

A new topological dimension is opened up: a psychic "within", separating "inside" from "outside", and phenomenology still builds on this, combining an internal perspective (informed by subjective experience) with an external perspective (informed by scientific experience).

The mega-molecules of life gradually assembled and converged into complex cellular structures. Life began to spread and the nascent cellular world evolved into a global super-organism, a living "film" (p. 54), bent on propagation and complexification from the very outset, giving rise to a first global crisis, by drastically transforming geosphere and atmosphere, producing oxygen (a toxic waste product) on a massive scale. The boundary zone between prelife and life teamed with proliferating minuscule beings: the biosphere appearing. Initially, however, life was a disruptive factor, and oxygen dramatically altered the atmosphere, until an equilibrium on a higher level of complexity was reached, turning oxygen into something positive: a requirement for proliferating aerobic life forms (the negation of the negation). Today, the advent of life can no longer occur spontaneously on Earth. Spontaneous generation now paradoxically (but quite dialectically) requires an abiotic environment: the absence of life. The primordial chemistry of life can be reproduced artificially, in laboratories (in vitro), where the creation and propagation of neo-life is already underway. Here the syllogism of generation (from chemical pre-life via biological life up to neo-life) can be consciously mimicked.

Life is an incessant arena of experimentation (p. 72), passing through multiple instances of negativity, passing over myriads of corpses, while the branches of the tree of life actually indicate the gaps left behind by vanished life forms (previous waves of natural experiments). But an axis of development can be discerned towards interiority and consciousness, culminating in the "plastic brains of primates" (p. 105). Evolution does not proceed randomly, but moves in the direction of orthogenesis (Procacci & Galleni, 2007). The emergence of mammals (with voluminous, convoluted brains) represents a decisive intensification of this tendency, as biogenesis gives rise to psychogenesis. Although the behaviour of insects is quite complicated and remarkable, their consciousness seems "frozen" into limited sets of functions. In mammals, consciousness becomes more flexible, although even here, development often becomes arrested as animals become prisoners of their external organs. In humans, evolution re-sculpts the brain via tool use and the emergence of language, eventually giving rise to a new geological and evolutionary era. The accelerated hominization of humans represents a leap-like mutation, superimposing itself on evolutionary continuity.

For Teilhard, as indicated, the scientific picture of human existence fails to capture the human phenomenon convincingly. Hominization is a decisive rupture, a moment of discontinuity, when consciousness begins to work upon itself (1955/2015, p. 110). Another world, another way of being-in-the-world is born (p. 111). Life entails a psychic transformation, from the obscure psyche of the first cells up to mammalian consciousness, and the human phenomenon represents a final leap, the awakening of intelligence: a hominizing metamorphosis (p. 114).

Self-consciousness is not a result of brain morphology alone, but a multi-factorial process. The freeing of the hands allowed early humans to gaze on what their hands took hold of (p. 115): a new beginning of subject-object interaction, giving rise to "another kind of life" (p. 116). The spark of reflection eventually affected the whole planet via the emergence and dramatic expansion of the noosphere: the thinking layer, the evolving global network of intelligent beings and their contrivances, over and above the biosphere (p. 124). A new type of being, a thinking animal invaded the planet, gradually eliminating or subjugating other life forms, creating an irresistible tide of fields and factories, resulting in planetary change: the advent of the "psychozoic" era (p. 124). Along the evolutionary curve there are particular points of dense creative activity (the appearance of life, of thought, of globalisation) and we are currently experiencing such a curvature (Teilhard de Chardin, 1969/1971, p 23). Seen from a distance, planet Earth now becomes "phosphorescent" with thought.

Initially the development and spread of fire, stone tools and pottery evolved quietly, but in the course of time, it resulted in a planetary wave of experimentation. We still recognise ourselves in the language of Cro-Magnon art, spiritually close to us (Teilhard de Chardin, 1955/2015, p. 139). Although the discovery of human fossils is one of the most illuminating and critical lines of modern research (p. 129), the true meaning and impact of the human phenomenon can only be grasped in the course of its unfolding. At this very moment, we are casting off the last moorings tying us to the Neolithic, agricultural era (p. 149). Via astrophysics and space travel, the human phenomenon is acquiring a cosmic scope. Our way of being evolves on a planetary scale, while the noosphere evolves into a new milieu, an intelligent ecosystem (p. 158).[2] We have been thrown out of the natural world into a neo-world of spiritualisation and civilisation. Comparable to the first experimentations of the first living cells, we now see the advent of waves of neo-life in laboratories (p. 156).

This triggers a sense of disquiet, a "crisis" of reflection (p. 158). Now that neo-life can be built up chemically (p. 159), we experience disorientation and malaise. Our sense of anguish, Teilhard argues, stems from the awareness that, as life has entered its thinking stage, evolution will from now on develop *via us*. According to Teilhard, scepticism and pessimism towards humanity is notably fashionable among intellectuals (the "luminaries" of his era), eloquently denying progress while stressing the absurdity of human existence. What we are actually facing, Teilhard argues, is a contemporary version of Pascal's wager (p. 163). We *must* assume responsibility for the undeniable fact that we are about to create new life-forms experimentally, while slow, Darwinian evolution (selection, random variation, struggle for life) becomes eclipsed by conscious experimentation (p. 171). Artificial neo-life is already emerging as a new phylum. A new realm of technology and reflection (and their material products) unfolds: a new "milieu", increasingly affecting the biosphere, similar to how life once significantly transformed the global geosphere and atmosphere. Heredity is increasingly becoming a revisable and transmissible legacy, is becoming thoroughly "hominized", and this inevitably gives rise to disquiet, for we seem unable to live up to the daunting challenges and responsibilities entailed in this. In the present situation, without precedent in the history of life, we suffer from collective psychic disorientation. More than at any other moment of history, Teilhard argues, we experience a fundamental anguish of being. Something threatening is opening up in front of us, and something seems more than ever lacking.

The co-authored autobiography by Jennifer Doudna, the Nobel Prize laureate who, together with Emmanuelle Charpentier, initiated gene editing via CRISPR-Cas9, resonates with this assessment. In *A crack in creation: the new power to control evolution* (Doudna & Sternberg, 2017), she explains how she, as a hyper-specialised researcher at Berkeley, had never realised that her microbial molecular tool might have dramatic social consequences in multiple realms of applications. This overwhelming awareness forced her to acquire new, transdisciplinary skills in fields like science policy, science communication, research ethics, and intellectual property rights (Zwart, 2019c). Her willingness to act as a responsible researcher (presupposing human agency and control) became questionable, however, in view of the unsettling experience that CRISPR-Cas9 rapidly seemed to assume a momentum of its own, spreading and developing via human researchers as vectors.

Somehow, however, uneasiness must be transformed into responsibility and foresight, Teilhard argues. We must learn to think and act collectively, assuming a planetary perspective. Teilhard's "optimism" (Grim & Tucker, 2006, p. 70; Grey, 2006, p. 109) stems from his conviction that reflection is likewise advancing towards a higher level. Via emerging means of interaction and communication, all human

[2] "The future will decide on the best name for this new era we are entering" (1955/2015, p. 149). In current discourse, the name Anthropocene has been adopted.

beings are now simultaneously present, and their deliberations are brought together on global podiums. Thus, we witness the emergence of pan-human options for investigation and reflection (p. 176). Self-consciousness is evolving into hyper-consciousness, via the noosphere as a planetary network of distributed intelligence and global deliberation: a psychic expansion, a decisive new leap in the development of the spirit. A turn of profound importance is taking place, right before our eyes. Due to this explosive acceleration of noogenesis, intelligence becomes "hyper-intelligence", and the human spirit evolves into a comprehensive, supra-individual "super-soul", an ultra-complex, ultra-conscious system, a synthetic confluence of thinking.[3]

Thus, egocentric contemplation is replaced by technification, collectivisation and industrialisation on a planetary scale, but we receive something in return: the invitation to participate in research and reflection as a collaborative techno-scientific project (1959, p. 246), a genuine *opus humanum*, conducted by global research networks, giving rise to an excess of consciousness, a golden age of knowledge production (p. 350). The world has acquired a new dimension: spatially, temporally and psychologically (1965, p. 165). We are witnessing a period of profound transformation, a restructuring of the spirit, enhanced by computer technology. Humankind is evolving into a global research team, and the earthly globe into a world-spanning laboratory, as the spirit of technoscientific experimentation proliferates. We are heading towards a new chapter in the evolution of life and human consciousness, a redefinition of being as such. This inevitably causes anxiety and malaise (1965, p. 171) and will even disrupt laboratory life in the traditional, artisanal sense (p. 170). We are dissatisfied because something seems absent or missing: a sense of direction, an ultimate collective target, something like a Holy Grail (p. 187).

As a final step, therefore, what is required is a conversion and sublation of science and spirituality (religion). Point Omega, the pole of consolidation, attraction and completion (1976/1978, p. 38), is drawing us in its direction (p. 82).[4] We are taken aback by the prospect of psychic hyper-expansion and intellectual superabundance, by the explosive acceleration of noogenesis, but we are nonetheless inevitably culminating towards point Omega (1955/2015, p. 257), allowing us to make the final leap to overcome inertia and unease (1969/1971, p. 90). Our narcissistic egos will dissolve into a higher, collective, hyper-reflective form of self-conscious "excessive reflection" (1959, p. 357) as a moment of fulfilment (pleroma). The noosphere will sublimate into a planetary layer of thought, but there are no summits without abysses, and therefore Omega, the transcendent pole of universal convergence, must draw us through our current moment of crisis.

[3] As indicated, Teilhard predicted the Internet and WWW as global forms of consciousness, linking humankind and giving rise to a "second axial period" (Delio, 2014, p. 1). Teilhard anticipated what is currently discussed as "singularity" and the "explosion of intelligence" (Kurzweil, 2005).

[4] For Teilhard, Christianity is a "religion of evolution" (Delio, 2014, p. 1), devoted to an evolutive God: Christ the evolver, drawing us towards fulfilment, towards Omega, guided by the Spirit.

Case History: A Teilhardian Assessment of Human Genomics

For Teilhard, the cosmos is an evolving process, while humans emerged along the evolutionary axis, representing a leap into self-consciousness. Billions of years ago, life began as a process of experimental sublimation, via permutations and combinations of genetic "characters" (p. 63) and now, evolution is becoming self-conscious and self-directed. In the recent past, human thinking already became increasingly mathematical and symbolic, allowing humans to modify their world by recombining algebraic numbers, chemical symbols and other "characters". And now heredity itself, until recently part of the biosphere, is transposed into the noosphere, allowing us to consciously recombine and adjust the biomolecular "characters" of chromosomal life (cf. Galleni & Scalfari, 2006, p. 167).

From a Teilhardian perspective, the *Human Genome Project* doubtlessly represents a decisive milestone along this axis. Modern science entails a process of progressive disenchantment, as the "imaginary" spherical cosmos (1959, p. 25) gives way to the evolving universe of technoscience, resulting in a decentralisation of humankind (disrupting self-centred worldviews of the past). There is something special about life in general and human existence in particular. As indicated above, whereas the general movement in the universe is towards entropy and dissipation, life evolves in a juxtaposed direction, ascending towards complexity: life as "negative entropy" (Schrödinger, 1944/1967), as the *negation of entropic negativity*. And while post-modernism in its rejection of the "grand narratives" of dialectics celebrates entropy, Hegel and Teilhard emphasise how life and consciousness work in the opposite direction (Burr, 2020). Technoscience intensifies this negative entropic trend, resulting in positivity, in increased complexity. Via biotechnology as a collective project, an *opus humanum*, we self-consciously redirect the course of evolution. This places us, not in a position of anthropocentric centrality, but of *eccentricity* (Teilhard de Chardin, 1959, p. 30), so that humankind (notably its technoscientific avantgarde) occupies a tilted, oblique position near the frontline of evolutionary progress.

Genomics as a research arena concurs with this scenario, sequencing and modifying the molecular *characters* of life, allowing technoscience not only to read, but increasingly also to recombine and "rewrite" the genotype, in the literal sense of "type" (Doudna & Sternberg, 2017; Zwart, 2012; Zwart, 2019c). Via the human sequence, we ourselves become the prime target of research and intervention. As Teilhard phrases it, human genomics reflects a concentration of contemporary research on ourselves (1955/2015, p. 110, p. 201), anticipating gene editing and genetic self-modification, transposing human genetics from the biosphere towards active noospheric reconstruction and evidence-based decision-making, informed by research conducted by large-scale, research consortia, employing automated high-throughput sequencing machines, replacing individual forms of inquiry by coordinated collective action.

The Human Genome Project (HGP) represents convergence and culmination in molecular genetics towards a thoroughly noospheric landscape, whose contours are explored by a "palaeontology of the future" (Teilhard de Chardin, 1959, p. 11). The absorption of heredity into the noosphere inevitably produces anxiety, Teilhard argues, for it is far from clear whether humans can be entrusted with this type of techno-scientific power, this ability to influence the future of (human) evolution. For Teilhard, the only solution, as we have seen, is a collective, supra-personal system of foresight and reflection, steering away from the abyss of anxiety, heading towards collective deliberation. According to Teilhard, this objective, the ascent towards hyper-reflection, is already discernible on the horizon as Omega, drawing us towards this future.

We are actively redirecting the course of natural history, but strictly speaking this is not due to us, humans. Something (the spirit of technoscience) has come *over* us, realising itself *through* us. Humankind is a carrier or vector, pointing towards a future that is predictable in outline, oriented towards re-synthesis and recreation. We will not only redirect evolution by producing new types of organisms, but also re-sculpt *ourselves*, our own heredity and brains. The artificial will accelerate and redirect the natural, notably because the techniques of transmission of written culture will increasingly be superimposed on genetic forms of heredity, while the organisation of research will increasingly fall under industrial control, resulting in a dramatic increase of pace and scale.

Something enormous was already introduced by industrial production and modern scientific technology, Teilhard argues, from giant telescopes down to atom smashers, but now the knowing subject itself becomes the target of technological intervention, so that the natural and the human sciences converge into a transdisciplinary science of hominization, bent on optimising human bodies and brains, with ethics and foresight replacing natural selection. This may even include "noble forms of eugenics" (p. 202), alongside a "reorganisation of the earth". After centuries of analysis, modern thought is now endorsing the creative evolutionary function of synthesis (p. 191), producing astonishing creatures, beautiful yet fragile experimental entities (p. 191). The conscious pole of the world is drawing the biosphere towards ultra-synthetic super-life, as the artificial is taking over from the natural (p. 198). Change is brought under active control as the techniques of scriptural transmission are superposed on genetic, chromosomal heredity. Evolution gave rise to the noosphere, enabling a global, noospheric organisation of research and the assemblage of "thinking beings" (p. 201). Let this suffice as a summary of Teilhard's vision. In the next section I will highlight the dialectical phenomenological fervour of his thinking, while also indicating how his optimism is problematized by other (congenial) thinkers.

Teilhard as a Dialectical Thinker

In a remarkably malevolent and hostile review of the English translation of Teilhard de Chardin's *The Human Phenomenon*, Peter Medawar (1961), once a big name allegedly, stated the following: "*The Phenomenon of Man* stands square in the tradition of *Naturphilosophie,* a philosophical indoor pastime of German origin which does not seem even by accident (though there is a great deal of it) to have contributed anything of permanent value to the storehouse of human thought". The second half of the sentence (indicative of the remainder of the review) may safely be ignored, but the first half is to the point. Intuitively, the author sensed, and rightly so, that Teilhard is a profoundly dialectical thinker; – although for Medawar this apparently counted as a perpetration, as a reason for outright rejection and expulsion.

In his history of French Philosophy, Frederick Charles Copleston likewise stresses profound "similarities" between Hegel and Teilhard, even though Teilhard "seems to have known little of Hegel" (1975, p. 323). For Copleston this spontaneous convergence is all the more telling. Both authors see the process of becoming as a process of progressive spiritualisation. Cosmogenesis is a dialectical unfolding, an immense drama in which the universe reveals itself to itself (Tarnas, 1991), evolving dialectically towards fulfilment. Although Teilhard was trained as a philosopher, he was primarily a scientist, an expert in paleo-anthropology, so that the concordance between Teilhard and Hegel may be considered an example of empirical science and philosophy working their way *towards each other* ("entgegenarbeiten", Hegel, 1830/1986a, § 12, p. 57).

Teilhard subscribes to the conviction that a dialectical logic can be discerned in natural and human history, which not only allows us to come to terms with the present, but also to anticipate (and actively contribute to the unfolding of) the emerging future. Dialectics strives to capture the present in thoughts, as we have seen, to conceptualise the *truth* of the current era, i.e. the most radical dimension of contemporary existence, spurring us to come to terms with it. For Hegel, the truth of modernity was the emergence of freedom, of the autonomous human subject. For Teilhard, the truth of the current era is the emergence of the noosphere, representing collective and distributed hyper-consciousness. Dialectics fosters self-reflection, raising awareness of how we ourselves are deeply immersed in the current process, but also outlining emerging options to critically assess and actively contribute to, and become part of the inevitable turn.

Whereas Hegel himself was ambivalent vis-à-vis evolutionary thinking, as was discussed in Chap. 2, Teilhard wholeheartedly endorses evolution, albeit not in the Darwinian sense, but as a dialectical process, spiralling towards increased consciousness and self-consciousness. Starting from a position of relative stability (equilibrium), challenges (negativity) may radicalise into crises, which may give rise to qualitative leaps, allowing nature to attain higher plateaus of complexity. Teilhard agrees with Hegel that the "end" of natural (Darwinian) evolution has been reached in the sense that the biosphere is increasingly affected by the noosphere: the conscious refurbishing of life, now that biotechnology is consciously recombining and adjusting genetic and biomolecular "characters".

There are indeed many instances of convergence between Teilhard's phenomenology (as elaborated in *The Human Phenomenon*) and Hegel's phenomenology (as elaborated in the *Phenomenology of the Spirit*). As point of departure for a comparative analysis, we may point to Teilhard's observation that scientific portrayals of the human phenomenon consistently fall short, since they lack a key dimension.

Precisely this same experience also plays a crucial role in Hegel's *Phenomenology of the Spirit*, most notably in his famous analysis of phrenology (skull anatomy), a research practice which started with the basic contention that the human phenomenon *is* (can be determined in terms of) a bone: the human cranium, the skull. For this, indeed, is phrenology's philosopheme: "*die Wirklichkeit und Dasein des Menschen ist sein Schädelknochen* (1807/1986, p. 250). Phrenology or skull anatomy builds on the grounding idea that bumps or indentation on the inside of the skull may indicate a person's *disposition*. That is how, in the case of phrenology, empirical science (observing consciousness) sees the relationship between anatomy and the mind. The skull is the immediate, tangible presence of the mind.

Evidently, Hegel is critical of this idea. Although one may freely associate in front of a skull, he argues, as Hamlet did with Yorick's, the skull bone as such is and remains an indifferent thing. By attempting to reduce the mind to its most tangible, but also most rigid form of being (a bone), the effort to study the mind anatomically quickly reaches a limit and becomes trapped in an impasse. The result is negativity: the *absence* of the phenomenon as such, demonstrating the deficit of the procedure. The dead skull cannot serve as a window into the living brain. The skull is, literally, the *negative* of the brain. The paradoxical result of phrenology, the moment of negativity, namely the *absence* of the living brain, of thinking and interaction, is an important experience nonetheless. Consciousness must now transcend this trap. It is precisely this deadlock which enables (and calls for) a dialectical turn towards a more comprehensive form of understanding. The deadlock of phrenology makes this turn towards a more comprehensive approach inevitable. We must look for mind or consciousness elsewhere, not inside the skull, but in our practical interactions with the world.

Paleo-anthropology, as practiced by Teilhard and his colleagues, can be considered as the actual outcome of a dialectically syllogism, with phrenology as its starting point. Phrenology began with the naïve conviction that consciousness is contained in the skull ("der Geist *ist* ein Knochen", M_1). This resulted in an impasse, and phrenology as a research practice (as well as the philosopheme in which it was grounded) was negated (M_2). Yet, skull research (starting with the discovery of the first Neanderthal skull in the Neander Valley in Germany in 1856, and of the first Homo erectus skull by Eugene Dubois in Java in 1893) does provide valuable evidence for the evolution of the spirit (the process of anthropogenesis), provided we see skull evolution as the *outcome* of a dialectical interaction between tool use, language and the environment. Friedrich Engels saw early human evolution precisely in this manner, presenting the process of anthropogenesis from primates to humans as a process of active interaction with the environment, of interaction between hands, speech organs, tool use and practical labour. What applies to the human hand (as a unique and singular organ, i.e. "*Einzelheit*"), also applies to the human skull: it is not only the enabling organ of human culture, but first and foremost the *outcome* or product of a long dialectical history of labour, praxis and interaction (1925/1962b, p. 445).

The Ascent of the Spirit and the Noosphere

Another important convergence between Hegelian and Teilhardian dialectics concerns the sublation from geosphere (chemistry and meteorology) and biosphere (life) to noosphere (spirit). Planet Earth began as a geosphere, a terrestrial meteorological system of physical and chemical (inorganic, abiotic) processes. Subsequently, the biosphere emerged, and transformed and absorbed the geosphere: a first sublation ("Aufhebung") on a global scale, onto a higher level of complexity and organisation. And now, the noosphere, the third step in the global dialectical process, increasingly absorbs and transforms both geosphere and biosphere, even superseding the tensions between the two (for instance by consciously adapting particular life forms to climatological conditions, etc.). Whereas entropy tends to pulverise organised entities into dust, life (biosphere) and technoscience (noosphere) evolve in the opposite direction. Thus, entropy is negated, "aufgehoben", so that both life (biosphere) and technoscience (noosphere) may serve as instances of the negation of the negation.

3.5 billion years ago, planet Earth (the primordial geosphere) gave rise to a diffuse super-organism, a living film: the biosphere, a green layer covering the abiotic geosphere (Teilhard de Chardin, 1955/2015, p. 94). Currently, Teilhard argues, we are on the verge of another decisive turn: the third moment of evolutionary logic. Via global human activity, a new layer is added, over and above the abiotic, inorganic geosphere and the biotic, organic biosphere, namely the noosphere, the "thinking layer" which, besides noetic *processes* and activities (thinking, calculating, modelling, communicating, deliberating, etc.), also involves noetic *products* (technologies, devices, infrastructures, computers, industrial plants, airplanes, and so on). It is distributed intelligence: a technological materialisation of Hegel's objective spirit, conceived as an extended, externalised and institutionalised structure on which individual intelligence, autonomy and creativity to a large degree depend (Boldyrev & Herrmann-Pillath, 2013). The noosphere evolves into a quasi-autonomous planetary network of advanced technologies and global circuits.[5] Humans are obviously animals, and yet we represent a discontinuity, giving rise to the emergence of the noosphere, relentlessly transforming and absorbing the geosphere and the biosphere, and one day (perhaps sooner than we think) we will be able to create artificial life (Teilhard de Chardin, 1955/2015, p. 249). Thus, the noosphere represents a conscious reshaping of the world, an epochal transformation affecting the entire planet. Indeed, it may even amount to an exhaustion of the earth and a frantic desire to invade other planets.

[5] Compared to Hegel's objective spirit, the noosphere concept emphasises the technicity, materiality and globalism of the emerging networks. Compared to the *technosphere* concept (the non-anthropocentric view that technology is a quasi-autonomous global phenomenon that follows its own dynamics and represents a new paradigm of Earth history: technology as the next biology, Haff, 2013), the noosphere puts more emphasis on thinking and spirituality.

Evolution and selection are being transposed from the biosphere ("nature") into the noosphere ("spirit"), leading to the emergence of neo-life (p. 250). In laboratories, life is becoming technologically reproducible (as exemplified by synthetic cell research, discussed earlier). For Teilhard, all this is not *due to* us, as we have seen. Rather, something has come *over* us, realising itself *through* us, something akin to Hegel's spirit, of which technoscience is the final culmination. What we currently experience is not a situation of human autonomy or mastery, but rather of "excentration", as Teilhard phrases it (1959, p. 30), for the unfolding of the noosphere entails the destruction of human egoism and self-centredness (1957, p. 93). Rather than being the centre of the universe, humans act as carriers or vectors, pointing towards a future which is predictable in outline (1955/2015, p. 224). Molecular "characters" (A, C, G and T, etc.: p. 226) are entering a new, technological milieu, as passive heredity is assuming a noospheric form. Life becomes a *concept*, and (in vivo) biomolecules transmute into (in silico) *symbols* (p. 247), so that heredity becomes spiritualised. Evolution becomes conscious of itself due to our ability to decipher, transform and rewrite the "characters" of life. As Hegel already phrased it, the spirit is now able to recognise (read, discern, etc.) its own symbolic logic in the "noumenal" essence of living nature disclosed by technoscience. Passive, slow and natural evolution is sublated into a conscious, accelerated and systematic global endeavour. The artificial is now carrying on the work of the natural, and the transmission techniques of literate culture (i.e. techniques for reading, editing and rewriting symbolic materials) are superimposed on genetic heredity. Conscious biomedical and moral concepts and considerations replace the randomness of natural selection. Life itself has brought into the world a power capable of criticising and improving it, and we are now awakening to the idea of a proactive, synthetic, humanised idea of evolution. Collective practical intelligence may now use these very technologies to domesticate and transform technology itself, so that the "laboratories" (Teilhard de Chardin, 1959, p. 128, p. 129) of nature and those of technoscience become reconciled again, and technoscience becomes bio-compatible again ($M_2 \rightarrow M_3$).

What seems obfuscated in Teilhard's technoscientific optimism, however, is a crucial implication of the entropy concept, namely that every increase in complexity, productivity and order (e.g. the emergence of life, of culture, of technoscience, of global metropolitan society, etc.) inevitably results in disruption elsewhere. In order to resist entropic disruption and safeguard complexity and organisation, we are constantly sacrificing and consuming ("negating") natural resources and natural entities. Ideally, this is part of a global metabolism, but the implication of the Anthropocene concept is that the human-nature metabolism has become irreversibly disrupted on a global scale (Foster, 2000).

Thus, Teilhard has been criticised for voicing techno-euphoria. His critics include a prominent dialectician, namely Jacques Lacan who argues that humankind has indeed "hominized" the earth, but first and foremost by *polluting* it (Lacan, 1966, p. 684). Now that the tiny symbols, the little characters and equations of quantum physics and molecular biology indeed allow us to manipulate nature, and even to enter the wider universe (via spacecraft), its Pascal-like immensity and silence no longer *frighten us*, seeing that we have begun to drop our garbage (our *noo-debris*) there as well. Indeed, the ability to ruin the earth, to destroy all life forms, including human life itself, would be a real "triumph", a real testimony of human "superiority" over other life forms, Lacan cynically argues (1960/1974/2005, p. 75).

Teilhard's response to such criticism is that, precisely in order to move away from the disruptive negativity of technoscience (M_2), we must develop a form of "hyper-consciousness" and "hyper-technology" (M_3). Without collective, concerted, planetary action, the negativity of rampant technoscience will indeed increasingly disrupt both the geosphere ("climate") and the biosphere ("biodiversity"), so that planet Earth will face accumulating contradictions and frustrations (M_2), a situation which must be sublated. This requires significant transitions on the side of the "spirit", the "noosphere" as well. Research and reflection must become organised on a planetary scale, similar to how laboratories become factories, via global processes of super-organisation (1955/2015, p. 283; 1959, p. 145, p. 152), collectivisation (1959, p. 218, p. 290) and "collective cerebralisation" (1965, p. 202), involving networks (e.g. the Internet) which turn abiotic matter into thinking systems (1955/2015, p. 251) and in which human brains (the final product of evolution) become increasingly entangled (1959, p. 105). The noosphere must evolve into a global network, a collective memory and intelligence of humankind, a spherical thinking circuit, a "brain composed of brains" (1959, p. 134), enabling distributed, transdisciplinary forms of analysis and synthesis, in order to live up to the requirements of the future.

We are pushing and pulled forward, towards a superior, collective form of intelligence: a new conceptual reality of pan-human discovery, reflection and intervention, bent on reconciling technoscience and nature on a higher level of complexity, and involving global humanity as a whole: a truly *opus humanum* (1959, p. 31). The noosphere, Teilhard predicts, will converge into a single system, a collective, planetary, electronic "super-consciousness" (1955/2015, p. 251; 1959, p. 95).

There are serious risks involved in this, such as the risk of being overwhelmed by a superabundance of information, by an explosive acceleration of noogenesis, relentlessly moving in a direction juxtaposed to entropy (1959, p. 93) and curving upwards towards "hyper-reflection" (1955/2015, p. 259). Here, Teilhard argues, instead of being at the mercy of our limited anthropocentric resources, the "spirit" will provide guidance in our irreversible ascending (1955, p. 273) towards illumination and convergence of research and reflection, of science and spirituality. During the "nadir" of the crisis, we sense the possibility of a final upward turn. Under the sway of the spirit, we may spiral towards the Omega point, the "supreme synthesis" (1959, p. 140), the final moment of convergence, reconciliation and unification (i.e. Teilhard's version of absolute knowing), where God and evolution no longer constitute two antagonistic centres of attraction (M_2), but rather enter into conjunction (M_3) (1959, p. 94). Towards the final act of the global drama, Teilhard's thinking becomes increasingly theo-compatible and theo-logical. In the next section, I will zoom in on Lacan's criticism briefly mentioned above, because it points to that which seems the most questionable aspect of Teilhard's assessment.

Teilhard and Lacan: From Skulls to Shells

At first glance, Pierre Teilhard de Chardin and Jacques Lacan represent juxtaposed positions in the intellectual spectrum of twentieth-century Francophone philosophy. On closer inspection, however, their oeuvres share important questions, insights and concerns. Although an extensive mutual confrontation ("comparative anatomy") of their parallel trajectories is beyond the scope of this section, a concise confrontation between their dialectical positions will prove mutually revealing, emphasising the relevance of both oeuvres for the planetary challenges we are facing today.

Teilhard never mentions Lacan, but on several occasions, Lacan mentions a "final conversation" he had with "Reverend Father" Teilhard de Chardin (on July 10, 1954), concerning the existence of angels[6] and the hominization of the planet. As indicated, Lacan agrees that, from the very beginning, we humans have "hominized" the planet, but first and foremost by *polluting* it, leaving behind a vast trail of garbage and waste everywhere we went. How could Teilhard, a palaeontologist, in his "optimism", overlook this (Lacan, 1966, p. 684)? According to Lacan, human waste and garbage (e.g. remnants of stone age industries) is what paleo-anthropologists are looking for in the first place.

That their "final conversation" focussed on angels is no coincidence, as both thinkers came from a catholic background.[7] Lacan grew up with an ardent Catholic mother and a younger brother who became a Benedict monk. Lacan himself attended a Catholic high school (the Marianist Stanislas College), married in church and baptised his first three children, while in later years he was in the habit of wearing an "almost clerical-looking" white shirt-collar (Roazen, 1996, p. 335). His oeuvre is replete with references to Catholic mystics (Eckhart, Hadewijch, Teresa, Angelus Silesius) and Catholic authors (from Saint Augustine and Blaise Pascal up to the Catholic mathematician Georges Gilbaud, who familiarised him with cybernetics and the topology of the Moebius ring). Also, Lacan's oeuvre contains many reflections on Mannerist and Baroque religious art, in accordance with the dictum that the repressed returns, albeit in another scene (de Certeau, 2006, p. 3). While Freud's writings reflect his Jewish background and Jung's oeuvre echoes his Swiss Protestant roots (combined with Gnosticism), Lacan's discourse is "deeply immersed" in (Francophone) Catholicism (Gale, 2016; Roazen, 1996).

---

[6] According to Lacan, their final dialogue revolved around the question of the existence of angels (1972–1973/1975, p. 30; 1976–1977, p. 66). Literally, an "angel" (ἄγγελος) is a messenger, a carrier of signifiers, transmitting the Word of the Other. According to Lacan, angels carry the (oral) object *a*, the breath (*spiritus*) which inspires and impregnates (cf. Baroque and Mannerist paintings of the Annunciation). *The ecstasy of Sainte Teresa*, the famous sculpture by Baroque artist Bernini, is discussed by Lacan in his Seminar *Encore* (1972–1973/1975). An angel holds a golden spear whose spear point (as "object *a*", prime object of desire) is about to pierce the entrails of the swooning saint.

[7] Teilhard sees Catholicism as a privileged cultural "phylum", an ascending cosmic force, an "evolutive faith" (1976/1978).

Professionally, Teilhard and Lacan represent two completely different worlds, but on closer inspection a basic affinity between palaeoanthropology and psychoanalysis is discernible. Freud himself had a keen interest in anthropology and archaeology. In *Totem and Taboo* (1913/1940), he interpreted contemporary neuroses against the backdrop of events which supposedly occurred during a primordial, paleoanthropological past. Like Teilhard, Lacan was highly interested in Cro-Magnon art, albeit influenced by archaeologist André Leroi-Gourhan (1911–1986), likewise professor at the Collège de France (from 1969 until 1982), who studied parietal drawings from a structuralist perspective, analysing the distribution of images in terms of patterns and binary oppositions. For Lacan, parietal art reflects the shift from the "imaginary" to the "symbolic" (1965–1966, p. 503), i.e. from art as a product of fascination (triggered by the amazing *Gestalt* of the depicted animal) towards images functioning as pictograms, as key symbolic elements (signifiers).

Teilhard and Lacan shared a mutual friend in French psychoanalyst Maryse Choisy, who was converted to Catholicism by Teilhard in 1936 (Roudinesco, 1986, p. 206) and founded the journal *Psyché: revue internationale de psychanalyse et de sciences de l'homme* in 1946, dedicated to furthering the convergence of psychoanalysis and Catholicism. Lacan was affiliated with her movement for some time.[8] Another personal link is Michel de Certeau (1925–1986) who joined the Jesuit Order in 1953 and became intrigued by Teilhard's work in the 1960s, publishing some of his texts and letters, but he also joined the Lacanian movement as one of the first members of the *École Freudienne de Paris* (EFP) in 1964. He co-directed the journal *Christus*, in which due attention was given to psychanalysis, and was appointed as professor at the "psychoanalytic enclave" (Highmore, 2006, p. 52) within the philosophy department at Paris-VIII Vincennes.[9]

Teilhard and Lacan were highly influential during the post-War period, albeit representing fairly different intellectual approaches and milieus. The rapid spread and reception of their ideas during the 1950s and 1960s concurred with the rise of molecular biology, eventually culminating in the double helix and the sequencing of the human genome, focussing on DNA (λόγος, pure code, as the beginning of life, cf. Collins, 2006). Both authors argued that scientific technologies allow us to redirect and redesign the course of (human) evolution. And both authors claim that science and technology reflect a tendency towards symbolisation, towards incorporation of the biosphere (living nature) into the "symbolic order" (Lacan) or "noosphere"

[8] In 1953, Choicy and Lacan visited Castel Gandolfo together to participate in a public audience by Pius XII (Roudinesco, 1993, p. 275). In 1954, Choisy and Lacan attended a reception organised in honour of Teilhard by the journal *Psyche* (Bousseyroux, 2013). During this meeting, a group picture was taken (with a crucifixion serving as backdrop), including Françoise Dolto, Jacques Lacan, Maryse Choisy, Rhoda de Terra, Louise Weiss, Pierre Teilhard de Chardin and Jean Hippolyte.

[9] Michel de Cerveau (2006) explores the catholic (Benedictine monastic) "archaeology" of Lacan's work. Like Lacan's *École*, a Benedictine monastery is a "school", established by a monk, after a retreat "in the desert" (Gale, 2016; Roazen, 1996), where a Master provides spiritual guidance by conducting a seminar (*lectio*) for his disciples, working through a text as a spiritual exercise, an ascetic practice, to recover an initial truth, resulting in the production of a new body of texts, allowing the word to re-incarnate.

(Teilhard). Like other scientific breakthroughs, the HGP entailed a "narcissistic offence" because, scientifically speaking (and contrary to initial expectations), there is nothing special about the human genome compared to genomes of other species. All genomes are written in the same 4-letter nucleotide script. And yet, only humans are able to sequence their genomes and reflect on their evolutionary history and future. As evolution becoming conscious of itself, only humans can be "offended" by the outcomes of genomics research.

Let us now zoom in on what seems their most telling point of divergence. In his *Écrits*, Lacan accuses Teilhard of "optimism" for ignoring the disconcerting by-product of human progress: global pollution (1966, p. 684). Humans have polluted the planet, thereby "hominizing" planet Earth, and have now even begun dumping their garbage into space. Landfills have been the hallmark of "hominization" of the planet since prehistoric times – how could Teilhard, a palaeontologist, forget this? From the very beginning, Lacan argues, humankind has "hominized" the planet by *polluting* it. We humans left behind a vast trail of waste and garbage, everywhere we went. For Lacan, palaeoanthropology is "garbage science" and a palaeoanthropology of the future will unearth incredible amounts of industrial and plastic litter left behind by current and future generations.

An interesting object of paleo-anthropological research, discussed by Lacan, are so-called "middens" (Lacan, 1965-1966; Zwart, 2015): pre-historic dumps of domestic waste, consisting of human and animal bones, excrements, botanical materials, mollusc shells, pot sherds and other artefacts and eco-facts associated with past human occupation. These middens are signifiers, carriers of a message, for instance because they may have served as indicators of human dwelling sites (this place is ours!). But they also perform this function in the *literal* sense of the term. Decades before Teilhard and colleagues unearthed *Homo erectus* skulls in China, the Dutch paleoanthropologist Eugène Dubois discovered the first Homo erectus skull near Trinil (Java). The fossil collection (now at Naturalis, Leiden) assembled by Dubois (or rather: by his team of convict excavators) also contained shells. Dubois, however, was obsessed with his singular skull (his "object *a*" which both saved and ruined his life: Zwart, 2019a), as the organ of thinking, but isolated from its context, its phenomenological "Welt". As a result, he neglected the waste, the heap of shells, as evidence of human praxis. This is why paleo-anthropology (like phrenology) requires a dialectical-phenomenological turn, focussing on the interaction between humans and their ecosystem, between *skulls* and *shells*. Recently, it was discovered that Homo erectus made miniature engravings in Solo River shells that were part of Dubois' collection, but apparently ignored by him: tiny geometric strokes, suggesting symbolic patterns (Joordens et al., 2015), although their meaning and function remain unclear: calendars, symbols, number counts, decorations, doodles? This discovery was quite astonishing, because the earliest previously known geometrical engravings were at least 300,000 years younger (Henshilwood et al., 2009). In other words, Dubois' fossils not only present case material for studying the progression of self-consciousness via cephalisation, but also reflect the dawn of the symbolic (of the signifier) as such (Zwart, 2019a). The symbolic order is not a product of brain evolution alone, but of the interaction between brain and environment, and we need both skulls and shells (or parietal art) to study it. Tool use gave rise to the clearing, the budding symbolic noosphere. According to Lacan, a signifier is basically an incision, a stroke, a marker, quite like the markings on Trinil shells. Maybe these strokes signified days or months, but in any case, they opened up a new dimension of experience, a symbolic clearing, through practices of symbolisation. At a certain point, these shells, these carriers of letter-like engravings, became littoral litter, became middens. Again, for Lacan, humans are first and foremost *litterers*, polluters, causing *le monde* to become *immonde*.

Lacan agrees that technoscience represents a dramatic restructuring and symbolisation of the Real, so that the organic, the biosphere (e.g. edible shellfish) becomes incorporated into a symbolic order (via inscriptions). Teilhard thematises this as "hominization" of the planet, resulting in a planetary symbolic system, a noosphere. What seems obfuscated by Teilhard, and emphasised by Lacan, is pollution as a by-product of progress. Humans are literate litterers. The genome is the symbolic, which technoscience aims to purify via symbolisation, but waste and pollution are symptomatic for the return of the repressed in the real. While genomes and skulls are *objects* of research of choice, the repressed returns as the *abject*. Human praxis is precisely this dialectical interplay between symbolisation and the real, between signifiers and refuse. Insofar as human progress exemplifies "negative entropy" (i.e. the tendency of life in general and human history in particular towards increased complexity and literacy), entropy will inevitably be produced elsewhere, in the form of accumulated litter. Future palaeontologists (or visitors from outer space) will discover the excessive extent to which the advance of human technoscience has polluted the global environment. And plastic litter will carry a logo, a set of letters, an inscription, representing the "logos" of technoscience.

References

Aczel, A. (2007). *The Jesuit and the skull. Teilhard de Chardin, evolution and the search for Peking man*. Penguin.

Barlow, J. (1992). The great work. *Electronic frontier column in Communications of the ACM*. https://w2.eff.org/Misc/Publications/John_Perry_Barlow/HTML/complete_acm_columns.html.

Cobb, J. (1998). *Cybergrace: The search for god in the digital world*. Crown.

Boldyrev, I., & Herrmann-Pillath, C. (2013). Hegel's objective spirit, extended mind, and the institutional nature of economic action. *Mind and Society, 12*(2), 177–202. https://doi.org/10.1007/s11299-012-0111-3

Bousseyroux, M. (2013). De l'inhibition comme suppléance : Artaud et Gödel. *L'en-je lacanien, 20*(1), 9–32.

Burr, J. (2020). Entropy's enemies: Postmodern fission and trans-human fusion in the post-war era. *Humanities, 9*(23), 1–8. https://doi.org/10.3390/h9010023

Collins, F. (2006). *The language of god: A scientists presents evidence for belief*. Free Press.

Copleston, F. (1975). *A history of philosophy 9: 19th and 20th century French philosophy*. Doubleday.

de Certeau, M. (2006). *Heterologies: Discourse on the other*. University of Minnesota Press.

Crutzen, P. (2002). Geology of mankind. *Nature, 415*, 23.

Deane-Drummond, C. (Ed.). (2006). *Pierre Teilhard de Chardin on people and planet*. Equinox.

Delio, I. (Ed.). (2014). *From Teilhard to omega: Co-creating an unfinished universe*. Orbis.

Doudna, J., & Sternberg, S. (2017). *A crack in creation: Gene editing and the unthinkable power to control evolution*. Boston: Houghton Mifflin Harcourt.

Engels, F. (1925/1962b). Anteil der Arbeit an der Menschwerdung des Affen. In F. Engels (Ed.), *Dialektik der Natur* (Marx Engels Werke 20) (pp. 444–455). Dietz Verlag.

Foster, J. B. (2000). *Marx's ecology: Materialism and nature*. Monthly Review Press.

Freud, S. (1913/1940). Totem und Tabu. In *Gesammelte Werke IX*. Imago.

Gale J. (2016). Lacan and the Benedictines. *European journal of psychoanalysis*. https://www.journal-psychoanalysis.eu/lacan-and-the-benedictines/

Galleni, L., & Scalfari, F. (2006). Teilhard de Chardin's engagement with science, technology and environmental ethics. In C. Deane-Drummond (Ed.), *Pierre Teilhard de Chardin on people and planet* (pp. 160–178). Equinox.

Garreau, J. (2005). *Radical evolution: The promise and peril of enhancing our minds, our bodies – And what it means to be human*. Broadway Books.

Greenfield, S. (2014). *Mind change: How digital technologies are leaving their mark on our brains*. Rider.

Grey, M. (2006). Cosmic communion: A contemporary reflection on the eucharistic vision of Teilhard de Chardin. In C. Deane-Drummond (Ed.), *Pierre Teilhard de Chardin on people and planet* (pp. 107–122). Equinox.

Grim, J. A., & Tucker, M. E. (2006). An overview of Teilhard's commitment to seeing as expressed in his phenomenology, metaphysics and mysticism. In C. Deane-Drummond (Ed.), *Pierre Teilhard de Chardin on people and planet* (pp. 55–73). Equinox.

Haff, P. K. (2013). Technology as a geological phenomenon: Implications for human Well-being. In C. N. Waters, J. A. Zalasiewicz, M. Williams, M. A. Ellis, & A. Snelling (Eds.), *A stratigraphical basis for the Anthropocene* (Special publications, 395). Geological Society. https://doi.org/10.1144/SP395.4

Hegel, G. W. F. (1807/1986). *Phänomenologie des Geistes* (Werke 3). Suhrkamp.

Hegel, G. W. F. (1830/1986a). *Enzyklopädie der philosophischen Wissenschaften I: Die Wissenschaft der Logik* (Werke 8). Suhrkamp.

Henshilwood, C. S., d'Errico, F., & Watts, I. (2009). Engraved ochres from the middle stone age levels at Blombos cave. *Journal of Human Evolution, 57*, 27–47.

Highmore, B. (2006). *Michel de Certeau: Analysing culture*. London/New York.

Joordens, J., et al. (2015). Homo erectus at Trinil on Java used shells for tool production and engraving. *Nature, 518*, 228–231.

King, U. (2006). One planet, one Spirit: Searching for an ecologically balanced spirituality. In C. Deane-Drummond (Ed.), *Pierre Teilhard de Chardin on people and planet* (pp. 74–95). Equinox.

Kurzweil, R. (2005). *The singularity is near*. Viking Books.

Lacan, J. (1965-1966). *Le Séminaire XIII: L'objet de la psychanalyse*. http://www.valas.fr/.

Lacan, J. (1966). *Écrits*. Éditions du Seuil.

Lacan, J. (1976–1977). *Le Séminaire XXIV: L'insu*. http://www.valas.fr/.

Lacan, J. (1972–1973/1975) Le séminaire XX: Encore. : Éditions du Seuil.

McLuhan, M. (1962). *The Gutenberg galaxy: The making of typographic man*. University of Toronto Press.

Medawar, P. (1961). Critical notice. *Mind, 70*, 99–106.

Procacci, S., & Galleni, L. (2007). Science, theology and the dialogue among cultures. *European Journal of Science and Theology, 3*(1), 5–515.

Roazen, P. (1996). Lacan's first disciple. *Journal of Religion and Health, 35*(4), 321–336.

Roudinesco, E. (1986). *La bataille de cent ans. Histoire de la psychanalyse en France 2 (1925–1985)*. Éditions du Seuil.

Roudinesco, E. (1993). *Jacques Lacan : Esquisse d'une vie, histoire d'un système de pensée*. Fayard.

Schrödinger, E. (1944/1967). *What is life? The physical aspect of the living cell/mind and matter*. Cambridge University Press.

Skehan, J. (2006). Exploring Teilhard's 'new mysticism': 'Building the cosmos'. In C. Deane-Drummond (Ed.), *Pierre Teilhard de Chardin on people and planet* (pp. 13–54). Equinox.
Sloterdijk, P. (2001). *Nicht gerettet. Versuche nach Heidegger*. Suhrkamp.
Smith, D. (2018). Phenomenology. *The Stanford Encyclopedia of Philosophy.* https://plato.stanford.edu/archives/sum2018/entries/phenomenology/
Spiegelberg, H. 1965. The phenomenological movement: A historical introduction*, Volume 1*. : Nijhoff.
Steffen, W., Grinevald, J., Crutzen, P., & McNeill, J. (2011). The Anthropocene: Conceptual and historical perspectives. *Philosophical Transactions of the Royal Society A, 369*, 842–867.
Steinhart, E. (2008). Teilhard de Chardin and transhumanism. *Journal of Evolution and Technology, 20*(1), 22.
Stock, G. (1993). *Metaman: The merging of humans and machines into a global superorganism*. Simon & Schuster.
Tarnas, R. (1991). *The passion of the Western mind*. Ballentine Books.
Teilhard de Chardin, P. (1955/2015). *The human phenomenon* (Translation: Sarah Appleton-Weber). Brighton/Chicago/Toronto: Sussex Academic Press.
Teilhard de Chardin, P. (1957). *Le Milieu Divin: Essai de vie intérieure* (Œuvres 4). Éditions du Seuil.
Teilhard de Chardin, P. (1959). *L'avenir de l'homme* (Œuvres 5). Éditions du Seuil.
Teilhard de Chardin, P. (1965). *Science et Christ* (Œuvres 9). Éditions du Seuil.
Teilhard de Chardin, P. (1969/1971). *Christianity and evolution*. Translated by René Hague. Orlando/San Diego, etc.: Harcourt.
Teilhard de Chardin, P. (1976/1978). *The heart of matter*. Harcourt.
Udías, A. (2009). *Christogenesis: The development of Teilhard's cosmic Christology*. American Teilhard Association.
Zwart, H. (2012). On decoding and rewriting genomes: A psychoanalytical reading of a scientific revolution. *Medicine, Healthcare and Philosophy: a European Journal, 15*(3), 337–346.
Zwart, H. (2015). Tainted food and the Icarus complex: Psychoanalysing consumer discontent from oyster middens to Oryx and crake. *Journal of Agricultural & Environmental Ethics, 28*, 255–275. https://doi.org/10.1007/s10806-015-9530-6
Zwart, H. (2019a). *Psychoanalysis of technoscience: Symbolisation and imagination* (Philosophy and psychology in dialogue). LIT Verlag.
Zwart, H. (2019c). Enter CRISPR: Jennifer Doudna's autobiographical assessment of the science and ethics of CRISPR/Cas9. *Ethics in Biology, Engineering and Medicine: An International Journal, 9*(1), 59–76. https://doi.org/10.1615/EthicsBiologyEngMed.2019030275

Chapter 8
Philosophy of Technoscience: From Cis-Continental to Trans-Continental

Taking Stock: The Noumenal Turn in Technoscience

The previous chapters explored how four (interacting and overlapping) continental approaches (dialectics, dialectical materialism, psychoanalysis and phenomenology) offer hints and guidance for coming to terms with the revolutionary dynamics and disruptive impact of contemporary technoscience. Hegelian dialectics provides a conceptual scaffold for developing a comprehensive view of the terrestrial system and even for addressing the Cambrian explosion currently unfolding in laboratories around the globe, as a result of technoscientific developments such as synthetic biology and CRISP-Cas9. Dialectical materialism likewise offers a conceptual framework for addressing the rapidly aggravating disruption of the metabolism between nature and global civilisation, and the ongoing convergence of biosphere and technosphere, exemplified by the synthetic cell. Francophone psychoanalysis, closely aligned with dialectical thinking, adds to our understanding of the specificity of technoscience, both as a practice and as a discourse, where technoscientific research emerges as a questionable vocation driven by a desire to control, but at the same time ostensibly out of control. The dialectical methodology of psychoanalysis was exemplified with the help of case histories, moreover, involving Majorana particles, gene drives, malaria mosquitoes and nude mice. The latter represent technoscientific commodities, exemplifying the assembly-line production of human-made organisms (the commodification of life as such). Subsequently, we demonstrated how Heideggerian phenomenology entails important methodological hints for understanding technoscientific artefacts against the backdrop of technoscience as a mobilising force and as a global enterprise. And finally, we outlined how Teilhard's views on the genesis of consciousness, self-consciousness and hyperconsciousness retrieve the historical (dialectical) dimension of phenomenology, thus allowing us to assess the present as a global unfolding of the noosphere.

H. Zwart, *Continental Philosophy of Technoscience*, Philosophy of Engineering and Technology 38, https://doi.org/10.1007/978-3-030-84570-4_8

Due to the revolutionary achievements of technoscience, philosophy initially seemed to become marginalised, resulting in "object loss", unworldliness and scholarly melancholia. In response to this, continental philosophy retreated into author studies (the library as a nostalgic shrine where the remnants of great thinking are preserved, interpreted and admired). At the other end of the spectrum, since the 1970s, applied philosophy and bioethics entered the scene, so that philosophy became split into two stratums, authors studies and bioethical applications, while the gap between the two seemed increasingly insurmountable. To live up to its pressing vocation of addressing the philosophical dimensions of challenging technoscientific developments and their societal impact, reflection became drawn into research genres such as bioethics and ELSA research (i.e. research into the "ethical, legal and social aspects" genomics, synthetic biology, nanoscience and similar fields), while many continental philosophers persisted in devoting themselves to author studies as an *Ersatzbefriedigung*. As Hegel already argued (1818/1986), however, the vocation of philosophy does not become irrelevant in the era of laboratory science. Quite the contrary: by taking up the unfolding challenge, a new dawn ("*Morgenröte*") seems imminent for a field that had been pushed beneath the bar as it were. An oblique philosophical perspective is as indispensable as ever, although in the current era a comprehensive assessment of the global "spirit" of technoscience requires distributed reflection, involving multiple voices and perspectives, rather than solitary Master thinkers, and resulting in a web-like, global, encyclopaedic process: the evolving outcome of a broad range of scattered but interacting research initiatives. Hegel himself already envisioned his encyclopaedia as a web-like structure (a diamond net of concepts), and Master-authorship has given way to scholarly networks of distributed scholarship, active around the globe.

Mid-way between Hegel and the present, the year 1900 looms up as an important axis point, when Gregor Mendel's work was rediscovered, the quantum concept was introduced by Max Planck, and Marie Curie Skłodowska demonstrated how radium spontaneously emitted light (at the first international physics conference in Paris), demonstrating the interwoveness of energy and matter. These events exemplified the dawning of a new scientific "spirit", as Bachelard phrased it, resulting in a new wave of technoscientific symbolisms, from Mendel's alphabet of dominant and recessive factors (Aa, Bb, Cc, etc.) up to the alphabet of elementary particle physics (e^-, P^+, H^+, H^o, μ, etc.). Not coincidentally, 1900 was also the year in which Freud inaugurated psychoanalysis (by publishing *The Interpretation of Dreams*) and Husserl initiated phenomenology (by publishing his *Logical Investigations*).

What exactly happened in technoscience, and in the world at large, in the *annus mirabilis* 1900? Philosophically speaking, the basic discovery of this scientific revolution, conveyed by core concepts such as "genetic mutations" and "quantum jumps", was the pivotal insight that nature *does* make leaps. While Charles Darwin, for instance, was still immersed in the logic of slow, continuous change (repeatedly quoting the adage *Natura non facit saltus* in *The Origin of Species*), the cesura marked by the year 1900 first of all concerned the sudden eruption of discontinuity thinking. Mutation is the biological equivalent of the quantum leap concept of quantum physics, as Schrödinger (1944/1967) convincingly argued. Thus, the year 1900 signifies the emergence of a metaphysical insight: of discontinuity as a philosopheme, unleashing a "metaphysical mutation", as Michel Houellebecq, (1998) phrased it, in his novel *Elementary Particles*. Moreover, discontinuity (leap-like change) results from the presence or absence of elementary components: from subatomic particles such as electrons (discovered in 1897) up to genes and nucleotides. Therefore, the miracle year 1900 boosted the symbolisation of life and nature, resulting in myriads of alphabets (e^-, P^+, H^+, H^o, μ, etc.; Ala, Arg, Asn, Asp, etc.; A, B, AB and O, etc.). In life sciences research, for instance, A, C, G and T exemplify the script (λόγος), the letters (στοιχεῖα) of life. Technoscience entails a convergence of physiology and linguistics, transcending the science – humanities divide.

Thus, a core attribute of the new spirit of technoscience was that it entailed a symbolisation or even obliteration of life and matter. In addition, the 1900 turn gave rise to the emergence of new technologies, from X-ray photography up to X-ray crystallography and particle accelerators. Last but not least, while during the 1920s the quantum concept gave rise to quantum physics and the rediscovery of Mendel to genetics (e.g. drosophila research), in philosophy we notice the advent of a continental philosophy of technoscience, represented by Gaston Bachelard (building on Freud and Husserl), but also by like-minded contemporaries such as Alexandre Koyré, Jean Cavaillès and Georges Canguilhem. In the 1920s, these authors (contemporaries of pioneer quantum physicists and geneticists) reinterpreted the history of science as a history of discontinuity, i.e. of ruptures, breaks and revolutions (Simons, 2019).

This spectrum of events allows us to capture the significance of the 1900 transition. As Bachelard phases it, in or around the year 1900, technoscience (technophenomenology) became *noumenology*. In other words, technoscience entailed a disclosure and symbolisation of the *noumenal* dimension of the real, revealing that the noumenal real (the "surreal" if you like) is rational (fathomable with the help of technological, symbolic and mathematical procedures). Genes and electrons are not "objects" in the traditional (phenomenal, Kantian) sense of the term. Technoscience revealed the "essence" of things: revealing, for instance, that a virus essentially is a package of genes, i.e. of rapidly replicating molecular informational code. Technoscience signifies how augmented research emancipated from our restricted mental and sensory capacities (so that physics became depth physics, biology depth biology, psychology depth psychology). And the carefully monitored interactions between subjects, instruments and objects (as actants) inside laboratories, is but a small sample of the trillions of interactions and relations, duels and confrontations which entities engage in, in the cosmic drama raging on a cosmic scale (Harman, 2011, p. 63).

Now that technoscience has evolved into molecular biology, X-omics and synthetic biology, and now that Darwinian evolution is rapidly being superseded by the radical technoscientific dexterity which allows humans to consciously modify the molecular programs of life, the impact of this noumenal turn is rapidly evolving before our eyes. The negation or *Entzweiung* that erupted between philosophical reflection and technoscience calls for sublation, for convergence of technoscientific and philosophical expertise. To phrase it in terms of a dialectical syllogism: the first moment entailed traditional research practices which relied on human mental capacities and sense organs and studied phenomena of continuous change (M_1). This was disrupted and negated by the new technoscientific spirit, emerging during the fin-de-siècle era (M_2). The basic philosopheme of continuity thinking ("Natura non facit saltus") was literally negated (by negating/obliterating the "non": "Nature facit saltus"). Discontinuous change was notably real at the noumenal level (e.g. mutations, quantum jumps). At the same time, discontinuity was discovered in the history of science as well (e.g. the micro-history of science, where discontinuous change was now studied from nearby, zooming in on research as a concrete praxis, on the basis of microscopic proximity as it were). The final step is the holistic turn from basic components to complexity, and from micro-reflection towards encyclopaedic aggregation, resulting in the development of a comprehensive, systemic view (M_3), also in philosophy, where microscopic case studies culminate in a diagnostic of the present and a prognostic of the future: a philosophy of the Anthropocene.

Both linguistics and molecular biology study the ways in which combinations of elements convey meaning (information). The overall trend in technoscience, now that life became technologically reproducible, is towards synthesis: a shift in orientation from analysis and "reading" (from genetics up to genomics sequencing) to recombing and "rewriting" (synthetic biology). Evolution no longer requires incomprehensibly vast intervals of time, now that time-lines become compressed, while minimal organisms and other contrivances foster productivity and acceleration in biomolecular research. The global genome and its promises ("promisomics", Chadwick et al., 2013) calls for global reflection (Thacker, 2005) which, besides ethical implications, should also explore metaphysical implications ("depth ethics"), while continental philosophy as a distributed global practice currently evolves from *cis*-continental to *trans*-continental.

Genomics paved the way for redesigning life via CRISPR-Cas9, Multiplex Automated Genome Engineering (MAGE) and similar tools (Doudna & Sternberg, 2017, Church & Regis, 2013). Streamlined versions of microbial genomes and industrial strains of proprietary microbes operate as engines of creation for the assembly-line production of plastic polymers, biofuels, pharmaceuticals, food ingredients, and other neo-products. According to technoscience celebrities such as George Church, anything imaginable can be put together by pre-programmable microbial manufacturing systems. On the global, systemic level, E. coli bacteria may eventually be dispatched to Mars to "terraform" the red planet. And once a sufficient level of aerobic *viriditas* has been achieved, humans may go and live there.[1] Bio-information (barcodes of life) may re-assemble minimal living beings from the chemical mayhem of Martian surroundings (Venter, 2013). Paradoxically perhaps, in an era of global crisis, technoscience is propagating unprecedented confidence in technoscientific prowess, spreading a millenarian credo for a new era (Bensaude-Vincent & Benoit-Browaeys, 2011). Evidently, continental philosophy

[1] Medieval scholar, abbess and composer Hildegard von Bingen (1098–1179) considered *viriditas* ('greenness') as the essence life (Newman, 1998).

should become intensely involved in these debates, guided by a pathos of proximity, a desire to combine critical questioning with pro-activity and relevance. Whereas androcentric biases entailed an exegetic focus on the oeuvres of exceptionally gifted Master-thinkers from the cis-continental past, philosophical reflection today evolves as a deliberative, distributed, embedded and global (trans-continental) activity.

The Technoscientific Revolution and its *Summa*

To capture the present in thoughts means to assess the current technoscientific revolution against the backdrop of previous revolutions. The "first" scientific revolution recorded by philosophical thinking was the dawn of thinking, the axis time (*Achsenzeit*) as Karl Jaspers (1949) phrased it: a global event, represented in the West by the birth of Greek philosophy and Euclidean geometry, culminating in Aristotelean dialectics. Being as such was conceived as a cosmos, in which a perfect geometrical harmony could be discerned: from the concentric heavenly spheres of ancient astronomy down to the elementary platonic solids (elements envisioned as cubes, pyramids, octahedrons, etc.). In ancient Greece, this revolution entailed a syllogistic movement, starting from the *whole* (the cosmos of geometric perfection, M_1), down to exploring the elementary *constituents* (the στοιχεῖα, M_2) of nature, while Plato's theory of the ideal state exemplified the third moment (M_3): a *concrete whole* which was consciously composed in accordance with the logic of Euclidean geometry, – and therefore in accordance with nature (κατά φύσιν). Aristotle's encyclopaedic oeuvre was likewise a concrete universal whole, where all concepts and discoveries (all products of ancient intellectual activities) were systematically processed and comprehensively assembled.

A similar development can be discerned during the medieval era. Now, the Aristotelean encyclopaedia (the ancient *result*) became the starting point (M_1), giving rise to the Islamic Golden Age (from Bagdad to Cordoba), where specific research areas were developed, complementing the Aristotelean corpus, e.g. algebra, astronomy, chemistry and medicine (M_2). This intellectual movement (realising the medieval νοῦς) subsequently spread to occidental regions, where it resulted in scholasticism (the effort to produce a synthesis between Aristotelean thinking and Catholicism, the true religion), but also in logic and experimental thinking (Roger Bacon, Cusanus, etc.), while medieval universities were conceived as strongholds of learning where all branches of research were brought together into a concrete comprehensive universal whole (M_3).

The modern scientific revolution emerged as the antithetic *negation* of Aristotelean thinking. This revolution unfolded during the early modern period and became associated with the discoveries of "scientific heroes" such as Copernicus, Galileo, Boyle, Newton and Lavoisier. Kant's *Critique of Pure Reason* can be considered the proverbial owl of Minerva, taking flight at dusk, providing the epistemological groundwork for this revolution, albeit retroactively as it were. His thinking was analytic rather than synthetic, resulting in a series of dichotomies (pure versus practical thinking, freedom versus determinism, subject versus object, the phenomenal versus the noumenal, etc.). In the context of this “second” revolution recorded by philosophy, we again notice a shift from a basic understanding of the whole – the deterministic universe (M_1) – towards analysing basic constituents, in the context of experimental research, zooming in on specific causal relationships, established with the help of precision instruments (M_2). Scientific experiments are concrete realisations of the logic of causality (e.g. Boyle’s experiments concerning the relationship between temperature and pressure of a gas). Yet, as Hegel already argued, in order to understand real nature (e.g. meteorology, the Earth as a system), a holistic turn is required towards a systemic approach (e.g. the Earthly atmosphere as a system of interacting factors: M_3). To achieve this, we must transcend the confines of the laboratory, as an insulated camera obscura, and develop a systemic and encyclopaedic view.

As indicated, the technoscientific revolution commenced around the year 1900 when Mendel was rediscovered, the quantum concept was introduced and Marie Curie demonstrated her radium research. Whereas the early-modern revolution revolved around the experimental method and the principle of causality, the technoscientific revolution gave rise to a new “spirit”, as we have seen, superseding the previous scientific revolution by disclosing the noumenal realm of elementary particles of life, energy and matter, and by unleashing research fields such as high energy physics and molecular life sciences, to study nucleotides, amino acids and subatomic particles (from protons and electrons down to the enigmatic Higgs boson) via a combination of advanced experimental technology and advanced mathematics.

This revolution is now culminating into a holistic turn (the third moment). In life sciences research, for instance, the technoscientific revolution can be summarised as a shift from *genes* (e.g. Mendelian genetics, the gene concept, the mutation concept, the emergence of genetics as a field) via genome sequencing and other -omics endeavours towards the synthetic biology of protocells and synthetic cells: as a converging effort, resulting in the synthetic cell as a concrete whole, a convergence of nature and technology, the *concrete universal* of life sciences research. In the synthetic cell as concrete universal, multiple strands of technoscientific research are systematically brought together: the synthetic cell as a technoscientific *Summa*. This dialectical turn towards co-construction and convergence (as the negation of the negation) is symptomatic of the new scientific spirit or zeitgeist, which entails a shift from reductionism towards complexity, so that the behaviour of an entire complex biological system is more important than individual molecular events (Luisi, 2006, xi; Simons 2019, p. 170). By opting for a systemic approach, the focus of inquiry shifts towards *interaction* (between nature and nurture, genome and environment, the technological and the natural, experimentation and computation, basic and applied research, etc.). Thus, the technoscientific revolution realises a shift from elementary particles (quantum physics, genetics, molecular life sciences, etc.) to complexity (understanding the behaviour of complex systems). Whereas technoscience initially focussed on electrons, protons, neutrinos, Higgs bosons, genes, nucleotides and other sur-objects, research is currently zooming out as it were from elementary particles to systems, from the physical laws of gasses to climate research, from sur-objects to mega-objects, or even hyperobjects (Morton, 2013).

At the subject pole of the knowledge production process, we notice a similar dynamic, a shift from differentiation (specialisation into disciplines and sub-disciplines) towards trans-disciplinarity and convergence, and from small-scale research programs to transnational research networks. The holistic turn requires intense collaboration across disciplinary fields. We see this in the development of research *technologies* (e.g. the emergence of "converging" and "enabling" technologies, the emergence of big machines, exemplified by particle colliders, large telescopes, space stations, next generation sequencing facilities, etc.), but also in the *organisation* of research (intense collaboration between research institutes, resulting in the rise of transnational research networks). Convergence of disciplines and institutes is a trans-continental trend, resulting in substantive connections between actors that up till now were operating independently. The restricted consciousness of individuals becomes sublated into a comprehensive noospheric mind or spirit. We may recognise a dialectical syllogism in this development, from small-scale research programs addressing general question via specialisation and differentiation up to convergence (trans-disciplinarity), resulting in the resurge of the idea of an encyclopaedic *Gesamtwissenschaft*, evolving in a distributed manner.

Convergence

In the global research arena, convergence is "in the air". In the U.S., the *National Science Foundation* presented a *Convergence Accelerator* to promote convergence research via "deep" interdisciplinary collaboration and partnerships, not only across disciplines, but also between academic and non-academic stakeholders.[2] NSF defines convergence research as a conjunction of former opposites: use-inspired and application-oriented research now closely *interacts* with basic, discovery-oriented research, while academic research groups team up with societal stakeholders (industry, not-for-profit organisations, government entities, and others), superseding the science-society divide. Convergence requires proactive and intentional management, as well as intensive re-education and mentorship. In March 15, 2019, the NSF Convergence Accelerator was presented via a "Dear Colleague" letter published on the NSF website and addressing the U.S. research community at large.[3] The NSF convergence accelerator focusses on two tracks, namely: "Harnessing the Data Revolution" and "Future of Work at the Human-Technology Frontier". Both themes are self-referential, i.e. directly relevant to technoscience itself, where a big data revolution is surging and research is outsourced to intelligent robotic machines.

[2] https://www.nsf.gov/od/oia/convergence-accelerator/

[3] https://www.nsf.gov/pubs/2019/nsf19050/nsf19050.jsp

Genealogically speaking, the NSF convergence initiative is part of a much longer history, which goes back to the birth of the NSF as such. The creation of NSF as a federal agency was proposed in 1945 by Vannevar Bush, head of the *Office of Scientific Research*, a governmental organisation devoted to managing big science projects, including the Manhattan Project. Vannevar Bush presented his proposal in a report to the U.S. President entitled *Science, The Endless Frontier*, calling for an expansion of government support for post-war scientific research. The report advocated a "big science" approach bent on overcoming the divide between basic and applied research. The Internet (which began as a project named ARPANET, funded by the U.S. military) can be regarded as one of the most notable results of this initiative. The ARPANET was established by the Advanced Research Projects Agency (ARPA) of the United States Department of Defence, and indeed, a substantial number of technoscience activities have been supported by the U.S. military. In the course of modern history, there has been a close alliance between research and the military, also in Europe, and scientific discourse is pervaded with militaristic terms (*strategy*, *mission*, *frontier*, *task force*, *cohorts*, *research intelligence*, *shot-gun approach*, etc.), starting with Plato, who referred to academics as *guardians* – in accordance with Hegel's adage, quoted by Ernst Kapp, that the military belongs to the "intelligence class" (Kapp, 1877/2015, p. 298).

Against this backdrop, the signifier "convergence" conveys a remarkable dialectical reversal. A dramatic dialectical trajectory has unfolded from the initial top-down big science scheme advocated by Vannevar Bush (e.g. the Manhattan project and the "qualified" knowledge it produced) down to current initiatives involving bottom-up stakeholder collaboration, user-oriented research, "bottom-up ethics" (Bard et al., 2018) and Open Science. Big Science projects such as the Manhattan Project entailed an intricate dialectical relationship between S_1 (the U.S. government and its representatives) and S_2 (the brain workers employed at Los Alamos, with Robert Oppenheimer as their chain-smoking research manager, cf. Zwart, 2017). Whereas in the Lysenko case the distance between S_1 and S_2 collapsed, as we have seen, in the NSF Big Science approach the distance was allegedly kept in place to some extent, so that scientists could focus on the technoscientific intricacies of their projects. Still, after the completion of the Manhattan project, politicians and the military *appropriated* the product of the brain-workers' labour (by assuming full control over the atomic bomb, the object *a* of nuclear physics), while Oppenheimer became a target of suspicion and was effectively marginalised (Zwart, 2017). At Princeton, he could retreat into "pure" science again, while from now on "classified" nuclear physics knowledge was considered the property of the state.

For the computer scientists working on ARPANET, this genealogy implied a complicated legacy. The history of the Internet continues to reflect this tension between S_1 (political power, initially represented by the United States Department of Defence) and S_2 (the researchers who wanted to develop a computer network for direct communication and exchange between research teams at universities). Soon, ARPANET escaped from the laboratory, infecting the outside world and evolving into the uncontainable and incontrollable Internet and its multiple bifurcations, the central nervous system of the noosphere.

In current convergence initiatives, we likewise notice a series of dialectical reversals, a dialectical syllogism. In the nineteenth century, research was often conducted by affluent amateurs, whose practices remained close to citizen science (M_1). In the context of technoscience, however, research evolved into a profession, and researchers became specialised brain workers in knowledge factories. This resulted in an epistemic divide between lifeworld experience and laboratory expertise (M_2). Convergence, however, entails the effort to bridge the gap between the two, transforming the lifeworld into a living laboratory (M_3) where myriads of research projects are occurring simultaneously, ranging from big data science (e.g. monitoring click behaviour of consumers) via crowdsourcing down to self-experimentation. Rather than on the expertise of technoscientific experts, the emphasis is now on their knowledge deficits, notably concerning the societal implications of the products of their research (Zwart et al., 2017). Research should become more "inclusive" (Macnaghten et al., 2014; Stilgoe et al., 2013), more sensitive to societal expectations and concerns, by broadening the spectrum of expertise, not only through interdisciplinary collaboration, but also by involving voices, experiences and perspectives from society. Participatory interaction should become an inherent component of research methodologies from the very outset, fostering public engagement and enabling easier access to scientific results (Open Science). In contrast to the deficit model, the focus is on knowledge and experiences available in society and relevant for research. The goal is to further positive societal impact by exploring and co-constructing possible scenarios and to co-create the future.

In the past, technoscientific progress resulted in "epistemicide", *negating* and obliterating practical and indigenous insights and skills ($M_1 \rightarrow M_2$), so that the development of scientific expertise evolved at the expense of other forms of knowledge and even resulted in the active liquidation and elimination of other (rival, traditional or indigenous) knowledge systems (Hall & Tandon, 2017). Now, all citizens are considered experts, to some extent (Collins, 2014). In other words, expertise has become ubiquitous ($M_2 \rightarrow M_3$). We all suffer from multiple knowledge deficits, in the sense that the future is open and indeterminate and it is difficult to predict how technologies will evolve and how the life-world will be affected. To address these deficits, collaboration and convergence (i.e. crowdsourcing distributed intelligence) is paramount. In living labs outside technoscientific laboratories, complex and potentially disruptive innovation processes are evolving, with technologies pervading the life-world, whilst they themselves will be affected by the way they are taken up and put to use. Thus, rather than denying (negating) the expertise of technoscientific experts, this entails epistemic interaction between multiple knowledge forms. Ideally, research is conducted under real-life circumstances. All the world becomes a laboratory, and large numbers of citizens participate in the research, collecting, sharing and questioning data.

Isabelle Stengers likewise argues that the specificity of science should no longer be thematised through hard demarcations between science vs. non-science, science vs. ideology, etc., as exemplified by scientific heroes such as Galileo and more recent versions of "science wars" (Stengers, 1993). Contemporary researchers have different concerns. Research is a creative and vulnerable practice, and scientists are struggling with burn-out, global competition and bureaucracy, e.g. of research funding organisations (Van Tuinen & Bordeleau, 2011). To forego mobilisation by dominant ideologies and power structures, researchers should opt for open science, but also for slow science: slow down! (Stengers, 2013). Science should not race ahead, but acknowledge the importance of interaction with "public intelligence". At the same time, this process calls for new forms of (social scientific) expertise, captured by a plethora of acronyms (STS, ELSI, ELSA, RRI, etc.)

Convergence entails a process of *Entäußerung* (externalisation, Malabou, 1996/2005), as technoscientific expertise opens up to different linguistic spectrums (to other voices). The discourse on "Responsible Research and Innovation" (RRI) explores how inhibitions and resistance among technoscientific experts against societal intrusion can be addressed (Carrier & Gartzlaff, 2020). Convergence is an *idea* which is actively at work, and its logic is becoming pervasive, also in terms of material conditions (infrastructure, training opportunities and funding mechanisms): convergence between Research Performing Organisations (RPOs, e.g. universities), between disciplines (transdisciplinarity), between academia and society (interactive research programs promoted by research funding organisation). The collaboration between academic and industrial actors indicates the extent to which technoscientific research has evolved into a global enterprise, as Heidegger contended.

Interactivity is emerging under various labels: RRI, Open Science, Citizen Science, crowdsourcing and the like. Knowledge deficits can only be addressed through collaboration, not only across disciplines, but also with participants from outside academia (citizen scientists). William Whewell, who invented the word "science", is also credited with coining the term "citizen science" and with organising what is now considered as one of the first paradigmatic citizen science projects, mobilising hundreds of volunteers internationally to study ocean tides. Another field with a long track record of participatory research (citizen science) is meteorology. Gregor Mendel, founding father of genetics, was also a citizen scientist, interested in weather-forecasting as the official weather watcher of Brno, taking meteorological observations daily and sending them to the Vienna Meteorological Institute. Accurate observation and mathematical treatment of data is characteristic of his work in this area as well (Zwart, 2008, p. 203). Meteorology developed vast networks of meteorological stations, so that all the world became a meteorological laboratory. After a period of professionalisation, research is again highly dependent on input from outsiders. Science requires distributed intelligence and participatory methodologies for data collection.

Distributed intelligence culminates in Wikipedia as a citizen science encyclopaedia, involving a global community of volunteers. According to the Wikipedia entry on "Wikipedia", 270.000 active contributors spend millions of hours on maintaining and developing it, and these numbers are continuously (if not exponentially) growing. Journals like *Nature* and *Science* constitute technoscientific encyclopaedias in their own right. Global research produces hypercycles of knowledge production. Etymologically speaking, encyclopaedia (ἐγκύκλιος + παιδείᾱ) can be translated as all-round education, indicating how the idea of a universal mind has now evolved from *homo universalis* into a network concept.

Thus, we move from a traditional encyclopaedia (written by professional experts, M_1) towards a dynamic network concept, where the gap between production and consumption of knowledge gives way to a global community of co-productive consumers (M_2). What is still missing in this massive externalisation, is what Hegel tried to achieve in his enormous project: a *philosophical* encyclopaedia of the arts and sciences, adopting an oblique perspective, a critical sublation of ICT-based discourse (M_3). This would involve a critical and systematic reading and processing of the discourses that are proliferating through technoscientific journals such as *Nature*, *Science*, *Cell*, *PLoS*, etc. In fact, this encyclopaedia is already emerging, albeit not as the work of one (or a limited number of) authors, but as a distributed research program: an emerging, trans-continental philosophical encyclopaedia, to which philosophers from various parts of the globe contribute in an interactive manner (including interminable peer review).

Discourse of Capitalism

We noticed how technoscience is externalising, becoming embedded in global society. This raises the question how technoscientific discourse operates under changing conditions. What kind of discourse is technoscientific discourse under present circumstances, and how does it function in the context of global societal developments? Technoscientific experts are qualified researchers (S_2 in the position of the agent), but they also constitute an authoritative voice (S_1 as powerful Other) whose authority is vehemently questioned by social discontent ($\$$ in the position of the agent). We clearly notice this in the context of the current COVID-19 crisis, for instance. Expert guidance is both called for (as a source of authority, a compass for policy and public behaviour) and vehemently questioned. How to determine the current structure of technoscientific discourse in terms of Lacan's four discourses?

Researchers who analyse the click behaviour of digital consumers with the help of advanced data analysis tools, are still operating within the syllogism of what Lacan referred to as university discourse. The expert (S_2) is the agent, and the clicking fingertip (routinely or hesitantly touching the Enter button) operates as object *a*. In the end, researchers may become frustrated, due to lack of relevance or replicability of the results ($\$$). As indicated in the previous section, however, the knowledge production process is currently drifting towards convergence and externalisation, so that researchers are interpellated by funding agencies and societal stakeholders to legitimise their work in terms of societal impact and boost the societal relevance of their findings. The force field of power and knowledge is shifting. We are not dealing with top-down governmental interventions, as advocated by Vannevar Bush, but with complex interactive processes involving both top-down components (interventions by funding agencies) and bottom-up (upstream) components (public involvement in the knowledge production process, a "democratisation" of knowledge even). What is happening?

One way of looking at it is to argue that technoscience has entered the global *agora:* a global market ambiance where various types of experts offer their views for sale (as in Lucian's play *Philosophers for sale*, but now on a global rather than on a polis scale) and where technoscientific products proliferate. According to Lacan (1972), neoliberalism is the Master's discourse of the present era, placing the market in the position of the governing principle. The Market is no longer a traditional Master interpellating us, however, but a "mutated", protean master (Pauwels, 2019; Olivier, 2009). On the global knowledge market, consumers are relentlessly requesting special products from technoscientific producers. Market mechanisms and digital platforms allegedly bridge the gap between production and consumption, so that consumers (end-users) may continuously interpellate knowledge producers. They may even co-constructively "produce" future products by claiming a say in the production of commodities, and in the knowledge agendas on which these are based. According to Lacan (1972), the neo-liberal market entails a mutation of the Master's discourse in the sense that it *inverses* the relationship between S_1 and *$*. This results in a "fifth discourse", a "mutant" of the discourse of the Master (Vanheule, 2016):

$	S_2
S_1	*a*

The consumer (driven by frantic desire, *$*) now directly confronts the technoscientific expert (S_2). The consumer (or end-user) is relentlessly interpellating established (validated) knowledge. What is the relevance and value of all this knowledge, who will be able to use it and when? Will it put an end to the COVID-19 pandemic, for instance, and the lock-down malaise? Can we speed up vaccine production, the object *a* of epidemiology: the tiny bottle of fluid, to be injected (through a mildly painful needle) into our bodies, so as to flatten the otherwise exponential pandemic curve? While technoscientific experts are monitoring disruptive global processes from behind their screens, and while pharmaceutical companies are producing their precious commodities on a massive scale, citizens and non-governmental organisations (NGOs) call for pro-active interventions. The *$* position (upper-left, acting as agent) may be taken by critical societal actors, including NGOs, but may also be adopted by researchers who are questioning the knowledge producing system themselves: experts who acknowledge their knowledge deficits and who become acutely aware of their shortcomings, plagued by self-doubt, questioning the validity of established knowledge, so that technoscience is becoming structurally pervaded with uncertainty. Yet, although the interpellation and questioning may seem authentic and critical, it may at the same time be instigated by the dominant ideology of neoliberalism (S_1) steering us "from below" as it were, pervading the scene. This may help to explain why questions and criticism arising in global societal debate are consistently articulated in terms of the dominant ideology: in neoliberal terms (e.g.

risks, consumer choice, product information, labelling, privacy, consent, intellectual property rights, benefit sharing, etc.).

Last but not least, if individuals become citizens scientists, if publics become actively involved in processes of knowledge production, who may appropriate the surplus value (*a*), the key products of all these efforts in the end? The Corona crisis may again serve as an example here. The initial object *a* is the vaccine, as we have seen, but gradually, displacement may occur, and the focus of attention may shift to something more symbolic, e.g. production numbers or stock exchange quotations of AstraZeneca and other pharma companies. COVID-19 triggers an avalanche of research activities around the globe, mobilising both experts (brain workers) and citizens. The latter are called upon to provide bodily samples in the context of COVID testing, for instance. In the end, however, the key *product* (i.e. the lower-right position in the scheme) is not knowledge as such. Rather, the intentionality of the research community (both academic and industrial) will increasingly focus on developing a commodity, so that the vaccine exemplifies the commodification of technoscience par excellence, representing that which is currently lacking – the object of desire, the immunising, life-saving fluid, which will allow us to overcome the current situation of hibernation and stagnation, and speed up again (the object *a*). The decisive question will be: who will own the property rights of this vaccine? Who can claim ownership rights? This is reflected in the current collision between AstraZeneca and the EU. While the latter provided 2 billion Euros of funding, AstraZeneca allegedly sold its precious commodity elsewhere. While countless researchers, citizens and patients will have contributed to its development, the surplus value (*a*) will be appropriated by the mega-players on the market. While knowledge may eventually serve the benefits of the public by producing special products (i.e. the user value of knowledge), the question remains who will receive the surplus value, who will own the intellectual property rights, the patents, who will receive future funding, acknowledgement and other forms of reward? If the position of *$* is actually taken by researchers, they may request revisions of the reward system for technoscientific research. Whereas traditional performance indicators serve as "perverse incentives" (*h*-score or stock exchange quotations as object *a*), critical voices may demand that we should rather go for real impact, relevance and solidarity.

$ (consumers desiring and demanding a vaccine)	S_2 (experts stressing the importance of safety and formal approval procedures)
S_1 (the adage that we are entitled to enjoy life to the full)	*a* (the vaccine: precious, questionable and controversial)

Lacan's intervention, the impromptu introduction of a fifth discourse, indicates that Lacanian psychoanalysis was (and should be) an evolving program, responsive to emerging developments, such as the eruption of the COVID-19 pandemic against the backdrop of neoliberal ideological dominance. The question is, how to master the logic that is actually at work here. Rather than from the "end-users" of technoscientific knowledge products, the interpellation may come from the pervasive logic of the market (from beneath the bar), so that the global market is the real Master

(M_1) who, also in this mutated discourse, continues to speak (via consumers) from underneath the scene.

Neo-Liberalism and Post-Truth

A final symptom of the discourse of capitalism concerns the vicissitudes of truth (the primal signifier of Western thinking) in the post-truth era. Public discourse (above the bar) entails an on-going confrontation between public discontent ($\$$) and technoscientific expertise (S_2) as we have seen, where the latter is represented by researchers, policy makers, managers of big data enterprises etc. The syllogism which aims to move smoothly from agents (vocal consumers) who address their demands to experts (as others), resulting in valuable products (*a*) is disrupted, resulting in symptomatic unintended by-products, revealing a disavowed truth speaking from beneath the bar. In the mutant discourse of neo-liberalism, there is still a truth speaking from beneath (S_1), but it is a kenotic truth, bereft of content: a "Master without qualities", representing the dictates of the calculative logic of the market.

This explains the current crisis afflicting the core signifier of Western thinking (ἀλήθεια), philosophy's primal word as it were: the crisis of truth. The fact that the *Oxford Dictionary* elected "post-truth" as "word of the year for 2016" is symptomatic of this predicament. A chronic disparity, rather than correspondence, has once again arisen between what we claim to know (knowledge) and what is happening out there (reality). The tension as such has always been there of course, as a stimulus for reflection and research. Plato already distinguished ἐπιστήμη (genuine knowledge) from δόξα (opinion). And when Jesus claimed that He had come into this world to testify the truth (John 18:37), Pilate (a scholar, well-versed in philosophy) famously retorted "What is truth?" (Τί ἐστιν ἀλήθεια; John 18:38), thereby entering into a dialogue which pointed to a disparity between the truth of this world and the truth of faith, – a disparity which medieval scholasticism aspired to supersede. More recently, as discussed in Chap. 4, Bachelard distinguished technoscientific validity (*fabricated*, literally, in laboratories) from preconceptions circulating in the lifeworld, from *cis*-truth as it were, at *this* side of the epistemic divide, not yet affected by the cathartic and kenotic operations of technoscience.

According to Heidegger, writing in the 1930s, however, this disparity has now radically aggravated, giving rise to what he referred to as a "collapse" of truth ("Einsturz der ἀλήθεια", 2014, p. 224). For Heidegger, this event was closely related to the radical instrumentalization and mobilisation of knowledge by what he referred to as meta-politics (Nazism, Americanism, Communism): the mobilisation of brain power by state power (as advocated by Vannevar Bush, for instance, in *Science: the Endless Frontier*, discussed above). In the context of global neo-liberalism (as a contemporary version of meta-politics) the political constellation has radically changed, but the crisis or collapse of truth has clearly manifested itself.

The post-truth era is characterised by a pandemic of disregard for truth. The global public environment has become a data-sphere, where terabytes of data are relentlessly circulating. The data deluge threatens to make the concept of scientific truth obsolete, to the extent that anything can be verified by adapting algorithms to desired outcomes. This results in an erosion of the credibility of technoscientific expertise (S_2), relentlessly interpellated by public discontent ($). Although many academics currently deplore this disregard for truth in the post-truth era, up to the point of launching marches for science (marches on behalf of scientific truth), they must be aware of their own involvement, to prevent becoming entrapped in the position of the Beautiful Soul (bemoaning the current crisis while overlooking how they themselves are deeply *involved* in what they deplore). For the erosion of truth has been actively promoted by academic scholars themselves. Researchers in the field of Science and Technology Studies (STS) should be mentioned here, for instance, intent on exposing how scientific facts are socially constructed. According to hardcore STS, scientific truth is determined by experts in the context of power games. Truth is the outcome of social processes and political negotiations, it is what certain self-serving coalitions of experts temporarily present as truth. For STS, the adoption of post-truth politics by politicians like Donald Trump evidently became a source of embarrassment, of trauma even. In 2004, Bruno Latour (one of the founding-fathers of STS) already criticised his own field for spreading the message that scientific facts are to be distrusted and that there is no such thing as truth. In retrospect, Latour deplored how right-wing "extremists", by questioning expert views concerning climate change for instance, appropriated STS strategies, so that their conspiracy theories seemed uncannily similar (in terms of argumentative structure) to former STS ideas. Latour now considered it a mistake that he had moved *away* from "matters of fact" (p. 231) and that he had contributed to "debunking science" (p. 232). According to Latour, post-truth politics is like critical radicalism gone mad, as if the STS virus of critique had escape from the scholarly laboratory, so that its deleterious effects could no longer be contained; as if the virus of criticism had mutated into a right-wing mutant and is now gnawing everything up (p. 231). Similar retractions were published by Sheila Jasanoff,[4] Sergio Sismondo (2017) and other TS protagonists.

How to respond to this situation from a continental philosophical perspective? Dialectically speaking, the response to this *negation* or even elimination of truth cannot be a relapse into a Master's discourse. Although a "return to" the oeuvres of previous thinkers (as a source of inspiration) is a crucial and recurring moment within a more comprehensive methodology, the ultimate objective is not restauration (the re-instalment of S_1 in the upper-left position, with experts functioning merely as oeuvre stewards). Rather we should aim for a *negation of the negation*, actively addressing the challenges emerging under current circumstances, thereby raising philosophy to its current task. The data deluge calls for an Encyclopaedia of the Philosophical Sciences 2.0. as a collective endeavour, articulating and

[4] http://first100days.stsprogram.org/2017/03/28/what-should-democracies-know/

questioning the basic philosophemes at work in current data flows, revealing how discourse under neo-liberal circumstances is driven by desire.

Under the sway of neo-liberalism, the focus of the knowledge production process is no longer on knowledge as such (S_2) but on the surplus value generated by the process (e.g. commodities enhancing enjoyment, *h*-scores, university rankings, Intellectual Property Rights, and other perverse incentives). Therefore, the discourse of the analyst focuses on the role of *a* as agent or actant. Performance indicators evolve into perverse incentives, frantically pursued by research communities under pressure who are drawn into action by these scores, sometimes even reverting to manipulation ($), for instance via data manipulation, author inflation, paper recycling, etc. Against this backdrop, continental (transcontinental) philosophical reflection aspires a critical reconsideration of the basic philosophemes at work in thus process (S_1). Besides "nature", "technoscience", "democracy", etc., this also involves a reconsideration and rehabilitation of the concept of truth. Like the question "What is nature?" discussed earlier, the question "What is truth?" may seem an impossible question, but it is also a question which has become impossible not to ask.

References

Bard, I., Gaskell, G., et al. (2018). Bottomup ethics: Neuroenhancement in education and employment. *Neuroethics, 11*(3), 309–322. https://doi.org/10.1007/s12152-018-9366-7

Bensaude-Vincent, B., & Benoit-Browaeys D. (2011). Fabriquer la vie: Où va la biologie de synthèse? Paris: Editions du Seuil.

Carrier, M., & Gartzlaff, M. (2020). Responsible research and innovation: Hopes and fears in the scientific community in Europe. *Journal of Responsible Innovation, 7*(2), 149–169. https://doi.org/10.1080/23299460.2019.1692571

Chadwick, R., et al. (2013). Editorial: From ELSA to responsible research and Promisomics. *Life Sciences, Society and Policy, 9*, 3.

Church, G., & Regis, E. (2013). *Regenesis: How synthetic biology will reinvent nature and ourselves*. Basic Books.

Collins, H. (2014). *Are we all scientific experts now?* Polity Press.

Doudna, J., & Sternberg, S. (2017). *A crack in creation: Gene editing and the unthinkable power to control evolution*. Houghton Mifflin Harcourt.

Hall, B. L., & Tandon, R. (2017). Decolonization of knowledge, epistemicide, participatory research and higher education. *Research for All, 1*(1), 6–19.

Harman, G. (2011). *The quadruple object*. Zero Books.

Hegel, G.W.F. (1818/1986). *Rede beim Antritt des philosophischen Lehramtes an der Universität Berlin*. Werke 9, 399–420. Frankfurt am Main: Suhrkamp.

Heidegger, M. (2014). *Überlegungen II-VI (Schwarze Hefte 1931–1938)*. Gesamtausgabe IV. Abteilung: Hinweise und Aufzeichnungen (Band 94). Klostermann.

Houellebecq, M. (1998). *Les particules élémentaires*. Flammarion.

Jaspers, K. (1949). *Vom Ursprung und Ziel der Geschichte*. Piper.

Kapp, E. (1877/2015). *Grundlinien einer Philosophie der Technik*. Hamburg: Felix Meiner.

Lacan, J. (1972). Du discours psychanalytique. In G. B. Contri (Ed.), *Lacan in Italia 1953-1978. En Italie Lacan* (pp. 32–55). La Salamandra.

Latour, B. (2004). Why has critique run out of steam? From matters of fact to matters of concern. *Critical Inquiry, 30*(2), 225–248.

Luisi, P. (2006). *The emergence of life*. Cambridge University Press.

Macnaghten, P., Owen, R., Stilgoe, J., Wynne, B., Azevedo, A., de Campos, A., Chilvers, J., et al. (2014). Responsible innovation across Borders: Tensions, paradoxes and possibilities. *Journal of Responsible Innovation, 1*(2), 191–199.

Malabou, C. (1996/2005). *The future of Hegel: Plasticity, temporality and dialectic*. Routledge.

Morton, T. (2013). *Hyperobjects: Philosophy and ecology after the end of the world*. University of Minnesota Press.

Newman, B. (1998). *Voice of the living light: Hildegard of Bingen and her world*. University of California Press.

Olivier, B. (2009). Lacan on the discourse of capitalism: Critical prospects. *Phronimon: Journal of the South African Society for Greek philosophy and the humanities, 10*(1), 25–42.

Pauwels, M. (2019). The most hysterical of masters: Lacan's capitalist discourse and contemporary styles of interpellation. *Psychoanalysis, Culture and Society, 24*, 53–71.

Schrödinger, E. (1944/1967). *What is life? The physical aspect of the living cell/mind and matter*. Cambridge University Press.

Simons, M. (2019). *The raven and the Trojan horse: Constructing nature in synthetic biology* (thesis). KU Leuven.

Sismondo, S. (2017). Post-truth? *Social Studies of Science, 47*(1), 3–6. https://doi.org/10.1177/0306312717692076

Stengers, I. (1993). *L'invention des sciences modernes*. La découverte.

Stengers, I. (2013). Une autre science est possible! In *Manifeste pour un ralentissement des sciences*. La découverte.

Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. *Research Policy, 42*(9), 1568–1580.

Thacker, E. (2005). *The global genome: Biotechnology, politics and culture*. MIT Press.

Van Tuinen, S., & Bordeleau, E. (2011). Isabelle Stengers. In S. van Tuinen, B. Ieven, A. Van Rooden, & M. Schuilenburg (Eds.), *De nieuwe Franse filosofie. Denkers en thema's voor de 21e eeuw* (pp. 440–452). Boom.

Vanheule, S. (2016). Capitalist discourse, subjectivity and Lacanian psychoanalysis. *Frontiers in Psychology, 7*, 1948. https://doi.org/10.3389/fpsyg.2016.01948

Venter, J. C. (2013). *Life at the speed of light: From the double Helix to the dawn of digital life*. Viking.

Zwart, H. (2008). *Understanding nature. Case studies in comparative epistemology*. Springer.

Zwart, H. (2017). *Tales of research misconduct: A Lacanian diagnostics of integrity challenges in science novels*. Library of ethics and applied philosophy 36. Springer. ISBN 978-3-319-65554-3.

Zwart, H., Brenninkmeijer, J., Eduard, P., Krabbenborg, L., Laursen, S., Revuelta, G., & Toonders, W. (2017). Reflection as a deliberative and distributed practice: Assessing neuro-enhancement technologies via mutual learning exercises (MLEs). *NanoEthics, 11*, 127–138. https://doi.org/10.1007/s11569-017-0287-4