How can we accomplish the changes needed to live sustainably on and with planet Earth? Today, few other questions seem to have an urgency to match this one. In It’s Alive: Ecological genomics and the promise of a new relationship with nature, Sanne van der Hout critically reflects on the opportunities offered by emerging ecotechnologies for realising a more sustainable relationship between humans, technology and nature. Her reflections focus on a particular case study: ‘ecological genomics’ or ‘ecogenomics’. This research field not only shows the potential of ecotechnologies for attaining a more sustainable future, but also demonstrates the difficulties entailed in the transition towards a new relationship with nature.
It's Alive!
Ecological genomics and the promise of a new relationship with nature
Sanne van der Hout
It’s Alive!
Ecological genomics and the promise of a new relationship with nature


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Preface: It’s Alive!

July 2011. As a PhD researcher, I participate in the ISHPSSB – ‘Ishkabibble’ for insiders – conference in Salt Lake City. Being there, my family and I grasp the opportunity to visit some of Utah’s and Arizona’s marvellous national parks. Having faced the wonders of Bryce Canyon, Grand Canyon, Sedona, Walnut Canyon, and Monument Valley, it is time to go home. On our way back to Salt Lake City, from where we will fly back to the Netherlands, we decide to make a detour to visit one final national park: the ‘red rock wonderland’ of Arches. Overwhelmed by the more than 2000 natural sandstone arches, our attention is suddenly struck by an information sign, saying “It’s Alive!” We see a cartoon of a big shoe and a bunch of scared, tiny creatures about to be crushed by it. The information sign warns us to stay on the trails; along the trails, we may notice patches of ‘cryptobiotic crust’, a remarkable plant community holding the desert sands together. The patches of black crust are “so fragile that one footprint can wipe out years of growth.”

The extent to which soil is imbued with life only became clear to me after I started with this PhD project. Trying to come to grips with the claims and promises in ecological genomics, I found out that a gram of soil contains more organisms than there are human beings on this Earth! Thus, it is not surprising that the soil has been defined as “the most useful and valuable habitat on earth” (Handelsman et al. 1998, 245). Soil plays a crucial role in preserving the health and productivity of crops, and in purifying our drinking water. Moreover, soil has been – and still is – essential to the discovery of new medicines such as antibiotics. In spite of this, “the human species often treats soil like dirt, polluting and degrading it” (Idem, 245). Why is this so? Why are we inclined to neglect the importance of soil? One reason might be our ignorance of soil life; the great majority of the processes beneath our feet are not only invisible but also unknown to us. Another possible reason has already been mentioned in the quotation; we tend to associate soil with ‘dirt’. This association is clearly reflected in the English concept ‘soiled’, meaning ‘dirty’. As I will show in the following pages, the overall objective of this thesis is to reflect on the potential of ecotechnology for realising a more sustainable future, using ecological genomics as a case study. However, ‘zooming in’ on this particular field of research, this thesis might also help to improve the image of soil, in other words, to promote soil sense and trigger our sensitivity to soil.¹

¹ In an article for the Dutch journal Filosofie & Praktijk, I have referred to ‘soil sense’ as ‘bodembewustzijn’ (Van der Hout 2012).
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Introduction
Towards a new relationship with nature?
How can we accomplish the changes needed to live sustainably on and with the Earth? Today, few – if any – other questions seem to have an urgency to match this one. “We live in a time of unprecedented and dramatic global change, in which the effects of human activities challenge the ability of natural ecosystems to buffer them” (Committee on Metagenomics 2007, 20). Because of its crucial role in exposing environmental damage as well as in controlling it, technoscience is often identified as “the ally and saviour of the environment” (Plumwood 2002, 38). Considering recent developments in the life sciences, its contribution to achieving the required changes seems very promising indeed; “having reached the limits of nature’s tolerance” (Benyus 2002, 1), we seem to have entered a new technological era in which we are ‘re-inventing’ our relationship with nature. Whereas more traditional technological approaches tend to disturb or interfere with the dynamics of nature (Sloterdijk & Heinrichs 2006), new technologies approach the natural world in a radically different way: they are increasingly inspired by “nature’s surprisingly effective design principles” (McDonough & Braungart 2002, 6). The desire to produce technological devices that mimic the natural world as closely as possible reveals an ecotechnological turn, meaning that nature’s own strategies, evolved over time, provide the models for our innovations.

1.1 Towards a more ‘natural’ natural science?

Since the global catastrophe began its partial unveiling, a new manifestation of the absolute imperative has come into the world, one that directs itself at everyone and nobody in the form of a sharp admonition: “Change your life! Otherwise its complete disclosure will demonstrate to you, sooner or later, what you failed to do during the time of portents!” – Peter Sloterdijk 2009a
The emerging ecotechnologies promise to dispense with traditional modes of science: whereas the latter are held responsible for producing the environmental crisis, the former are said to take the lead in curing it (Benyus 2002; McDonough & Braungart 2002; Sloterdijk & Heinrichs 2006). This thesis critically reflects on the opportunities offered by ecotechnologies to bring about a new, more sustainable relationship between humans, technology and nature, by ‘zooming in’ on a particular case study: ecological genomics, sometimes abbreviated to ecogenomics. As I will show in the following sections, this research field not only gives a clear account of the potential of ecotechnology for realising a more sustainable future, but also shows the difficulties of the transition from ‘old’ to ‘new’ approaches to nature.

1.2 The ecogenomics revolution

Since the beginning of the twentieth century, our understanding of the role of genes in living systems has increased dramatically. The “century of the gene” (Keller 2000) started in 1900 with the rediscovery of Gregor Mendel’s work on plant hybridization by Hugo de Vries, Carl Correns, and Erich von Tschemak, and ended with the announcement that the Human Genome Project (HGP) – devoted to the identification of all the genes on the human genome – was rapidly approaching its completion (Zwart 2007). In the years that followed, it became evident that genomics comprises more than the HGP alone. Even though the HGP “has been extremely important in creating public awareness of the science, from the perspective of the researchers it is really a sideline” (Parry & Dupré 2010, 4). The HGP played a crucial role “in mobilizing and channelling resources into genomics, thus having ramifications across the wider area” (Idem, 5).

One of the areas strongly affected by the ‘genomics revolution’ is ecology. “In the ecological arena, the interaction between genomics and ecology has led to a new field of research” (Van Straalen & Roelofs 2006, 1), generally referred to as ecological genomics or ecogenomics. Nico van Straalen and Dick Roelofs, authors of the first textbook entirely dedicated to this field, define ecological genomics as

“a scientific discipline that studies the structure and functioning of a genome with the aim of understanding the relationship between the organism and its biotic and abiotic environments” (Idem, 1).

Following this definition, it might appear that the main objective of ecological genomics is to apply a new ‘tool’ – i.e. genomics – to the analysis of fundamental ecological questions. However, Van Straalen and Roelofs emphasise that “the merging of genomics with ecology includes more than the incorporation of a toolbox, because with the new technology new scientific questions emerge and existing questions [in ecology] can be answered in a way that was not considered before” (Idem, 1). Similar expectations are expressed by Mark Ungerer and colleagues: “Such an integration of fields […] will revolutionize our understanding of a broad range of biological phenomena” (Ungerer et al. 2008, 178). Moreover, Martin Feder and Thomas Mitchell-Olds, generally referred to as the ‘founding fathers’ of ecological genomics, underline that “this approach has provided new insights that were not available from its disciplinary components in isolation” (Feder & Mitchell-Olds 2003, 649).

Why is ecological genomics considered such a great leap forward? What kinds of new questions emerge with the new technology? And why is the field believed to provide new ways of tackling existing problems? To answer these questions, we first of all need to understand that ecological genomics seeks to bring about a marriage between disciplines that are rooted in different – some would even say hostile – research traditions:

“Ecological and laboratory-based genetic/genomic investigations traditionally have occupied different areas of the biological sciences […] With a few notable exceptions, research programs
are generally positioned in one domain or the other, but do not regularly cross the boundary that separates these disciplines by utilizing the tools and approaches of both" (Ungerer et al. 2008, 178).

Joop Ouborg and Wim Vriezen provide a clear description of the differences between both types of investigations:

“Molecular biologists prefer to work in controlled environments and with homogeneous well-defined genetic material, aiming to remove as much variation as possible. For ecologists, environmental and genotypic variation is their core business, which they try to incorporate in experimental designs rather than controlling for it” (2007, 13).

Ecological genomics seeks “to fine-tune the experimental designs of ecology and molecular biology in order to accomplish true integration of the data that originate from these two fields” (Idem, 14). Such an integration is expected to be beneficial to both partners in the ecological genomics marriage: “ecology is enriched by genomics technology and genomics is enriched by ecological questioning and evolutionary views” (Van Straalen & Roelofs 2006, 3).

1.3 Promises in ecological genomics

The emerging field of ecological genomics is “couched in promissory terms” (Parry & Dupré 2010, 4). The claims, promises, and suggestions surrounding the field are developed in a number of directions. First of all, the ‘ecogenomics revolution’ is pictured as a new form of knowledge production in ecology. By bringing together field-based ecological research and laboratory-based genomic investigations, ecological genomics is believed to bring about a “paradigm shift” in ecology. The Committee on Metagenomics compares the emergence of ecological genomics “to a reinvention of the microscope in the expance of research questions it opens to investigation. [The field] has the potential to revolutionize our understanding of the entire living world” (2007, 2). Ecological genomics is indeed expected to lead to a whole new way of looking at natural systems. In conversations with ecological genomic experts, it was frequently mentioned that the integration of ecology with genomics resulted from the readiness of scientists “to look beyond the boundaries of their own research disciplines” (Nicole van Dam, interview, August 2010). Or, as Nico van Straalen put it, the field makes use of universal, rather than clear-cut principles (Interview, March 2009). In scientific publications, the transdisciplinary nature of ecological genomics is said to reveal a holistic approach. Kemperman and colleagues, for instance, claim that ecological genomics allows “a wider, more holistic approach” to the analysis of ecosystem processes (Kemperman et al. 2010, 3224 – my emphasis; cf. Guazzaroni et al. 2010, 56; Van Straalen & Feder 2012, 4). Some experts even go so far as to refer to the field as the “genomics of Gaia” (Committee on Metagenomics 2007, 139).

The second claim at the core of ecological genomics includes promises for society as well as for nature: ecological genomics is presented as a field that will serve human needs, while at the same time respecting the integrity of ecosystems. Notably in programmatic documents, ecological genomics is presented as a field with high potentials for nature-friendly applications in the areas of agriculture and environment. This is for example claimed by the Dutch Ecogenomics Innovation Center (ECOLINC) – formerly known as the Ecogenomics Consortium – whose objective is to enhance “our understanding of the functioning of ecosystems, with the aim to unlock the full genetic potential for sustainable use of ecosystems for agricultural

2 SenterNovem [http://www.senternovem.nl/bsik/projecten/artikelen/gezond heidsoorbraken/ecogenomics] – last accessed 8 October 2009. SenterNovem no longer exists as a separate agency; it has been incorporated in the Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland), which is part of the Ministry of Economic Affairs (RVO.nl).
we seem to have entered a new chapter in the history of technology, in which we redefine our relationship with nature (cf. Ball 2001; McDonough & Braungart 2002; Sloterdijk & Heinrichs 2006). Whereas more traditional technological approaches see nature basically as “a conglomeration of natural resources, a storehouse of materials” (Evernden 1993, 10), new technological approaches are increasingly inspired by the design principles of nature. They borrow from nature’s own pool of technologies and initiate applications that are strikingly similar to nature’s own processes, up to the molecular scale. As has been argued at the beginning of this chapter, this wish to develop technological devices that mimic nature’s processes as closely as possible reveals an ecotechnological turn, meaning that nature’s own evolutionary strategies provide the models for our innovations.

It is interesting to see how the above-mentioned claims are connected: the idea is that by means of a more thorough understanding of ecosystem processes, societal needs can be met in more intelligent, sustainable, and even ‘natural’ ways. Thus, it is precisely as a new, more comprehensive form of knowledge production that ecological genomics is expected to meet human needs in a more sustainable fashion.

1.4 The ecotechnological turn

The claims and promises surrounding the ecological genomics field should not be considered in isolation: they are representative of broader developments within today’s life sciences. Over the past few decades, we have discovered that nature’s mechanisms and processes are much more complex, intricate and interwoven than we ever imagined. Moreover, we have become increasingly aware of the Earth’s vulnerability to human interventions. As “[w]e can see, more clearly than ever before, how nature works her miracles” (Benyus 2002, 6),

and other anthropogenic purposes.” According to ECOLINC, ecological genomics will provide “essential services for improved environmental protection,” for instance by developing tools “for monitoring the impact of pollutants on ecosystems and for cleaning up contaminated environments” (George et al. 2010, 119). The field is therefore said to break the ground for a sustainable “Biotechnology for Nature.”

It is interesting to see how the above-mentioned claims are connected: the idea is that by means of a more thorough understanding of ecosystem processes, societal needs can be met in more intelligent, sustainable, and even ‘natural’ ways. Thus, it is precisely as a new, more comprehensive form of knowledge production that ecological genomics is expected to meet human needs in a more sustainable fashion.


ECO
ECO

6 In the reference list at the end of this thesis, I have added the English language editions that I have used as guidelines in translating Sloterdijk’s work from German to English.
under revision. “We are witnessing that with intelligent technologies a non-dominant form of operativity is emerging, for which we propose the name homeotechnology” (Sloterdijk 2001, 227). Whereas allotechnologies neglect nature’s own principles of operation, homeotechnologies (derived from the Ancient Greek ὀμοιός, meaning ‘alike’ or ‘similar’) are similar to and compatible with nature’s own processes. Instead of enslaving and exploiting nature, “the ‘materials’ are [...] conceived in accordance with their own stubbornness, and are integrated into operations with respect to their maximum aptitude” (Idem, 227).

There are some similarities between Sloterdijk’s concept of homeotechnology and the ‘learning from nature’ movement put forward by Janine Benyus as biomimicry: “a new science that studies nature’s models and then imitates or takes inspiration from these designs and processes to solve human problems” (2002, front pages). According to Benyus, the ‘Biomimicry Revolution’ puts an end to the era in which the general belief was that “the world was put here exclusively for our use” (Idem, 8):

“In a society accustomed to dominating or ‘improving’ nature, this respectful imitation is a radically new approach, a revolution really. Unlike the Industrial Revolution, the Biomimicry Revolution introduces an era based not on what we can extract from nature, but on what we can learn from her” (Benyus 2002, 2; cf. Bensaude-Vincent et al. 2002, 2).

1.5 Tensions in ecological genomics

In the previous section, I explained that the claims and promises at the core of ecological genomics are representative of a broader ‘ecotechnological turn’, meaning that nature’s own principles of operation increasingly provide the models for human innovations. This turn cannot only be observed in various areas of the life sciences, but has also been described by contemporary environmental thinkers such as Sloterdijk. A central claim entailed in (philosophical assessments of) ecotechnological discourse is that a more thorough understanding of nature’s own dynamics will help us to meet human needs in a more sustainable manner. In this thesis, I will critically reflect on this claim, using ecological genomics as a case study. Earlier I argued that, as a new, more comprehensive form of knowledge production, ecological genomics is expected to form the basis of a more sustainable use of ecosystems for a variety of societal purposes. However, ecogenomics discourse shows that this claim comes with a number of tensions and ambiguities that require to be more explicitly addressed. Such an exploration will not only deepen our understanding of what is at stake in this particular field of research, but will also prove to be relevant for interpreting the ecotechnological turn in a broader sense.

A first tension relates to the epistemological profile of ecological genomics, i.e. to the kinds of insights and forms of knowledge the field is expected to produce. To put it differently: it deals with ecological genomics as a new form of knowledge production in ecology. Ecological genomics is presented as a field that promises to bridge the gap between ecological and genomic investigations. However, the focus in ecological genomics as it has developed so far seems to reflect a ‘genomicalisation’ of ecology rather than an ‘ecologisation’ of genomics. As Ouborg and Vriezen argue, “due to the current nature of technical tools and model species [ecological genomics] currently seems to be orientated more towards ‘genomics’ than towards ‘eco’” (Ouborg & Vriezen 2007, 14; cf. Feder & Mitchell-Olds 2003; Ungerer et al. 2008).

Thus, in spite of the attempt to reconcile the languages of ecology and genomics, the two as yet seem to have only partially met.

A second tension relates to the normative profile of ecological genomics, notably the claim that ecological genomics will meet human needs, while at the same time respecting the integrity of ecosystems. As mentioned before, this claim includes promises for society as well as for nature. Or, to put it differently, it contains both an anthropocentric...
and an ecocentric element: the opportunities created by ecological genomics are not only beneficial to humans, but will also ‘serve’ the natural environment. This twofold promise is for example expressed in the statement that ecological genomics will help us to “maintain the health of the soil for agriculture as well as for nature”, or in the assertion that the field will “reveal ways to meet myriad challenges in biomedicine, agriculture, and environmental stewardship” (Committee on Metagenomics 2007, 31). However, there is a tension between the societal and ecological promises of ecological genomics. This tension is revealed by disagreements about the future direction of the (Dutch) ecological genomics field. Whereas part of the community mainly seeks to exploit the field’s potential for useful applications, others fear that this focus on economic ‘valorisation’ will undermine the “further development of basic and fundamental scientific knowledge” (Ouborg et al. 2009, 3). The difficulty of integrating societal and ecological goals is also reflected in the images, metaphors, and narrative structures with which ecological genomicists seek to illustrate and legitimise their research activities. The imagery that currently dominates ecological genomics discourse expresses a “productivity outlook on nature” (Worster 1994, 271), for instance when the metagenomic practice of uncovering the Earth’s microbial diversity is compared with a quest for a treasure (e.g. Oh et al. 2003, 248; Schoenfeld et al. 2010, 20).

To sum up, the tensions revealed in ecological genomics discourse revolve around three promises:

1. A scientific promise: ecological genomics will bring about a marriage between genomics and ecology.
2. A societal promise: ecological genomics has great potential for serving agricultural, medical, industrial and other societal needs.
3. An ecological promise: ecological genomics will meet these needs in more intelligent, sustainable, and even ‘natural’ ways.

These three promises, we must remember, are interlinked: exactly as a more comprehensive form of knowledge production, ecological genomics will enable us to meet human needs in a manner “consistent with the ecological fabric of the greater life system” (Mathews 2011, 366). Moreover, these promises are not exclusive to ecological genomics, but are representative of broader developments within the life sciences, in which we can observe an ‘ecotechnological turn’, i.e. a turn in which nature’s own principles of operation increasingly provide the models for our innovations.
1.6 Towards a new relationship with nature?

This thesis uses ecological genomics as a case study to reflect on the promises of ecotechnology. As a research field, ecogenomics not only endorses the expectations (described above) concerning the potential of ecotechnology for realising a more sustainable future, but also shows the difficulties entailed in this transition towards a new relationship with nature. The research question to be addressed in this thesis is as follows:

*To what extent does ecological genomics discourse, as an exemplification of the ecotechnological turn, reflect the possibility of a new relationship between humans, technology and nature?*

This overarching question contains a number of sub-questions, such as: What exactly are the promises entailed in ecological genomics discourse? How can a new relationship between humans, technology and nature be achieved and how can ecological genomics contribute to this?

In answering these questions, I will follow two ‘paths’. Firstly, I will analyse self-presentations and self-understandings of ecological genomics as articulated in scientific publications, programmatic documents, research proposals, conference talks, etc. Earlier, I explained that ecological genomics seeks to bring about a marriage between disciplines that are rooted in different research traditions. The disciplines at the core of the field “interpret the natural environment in different ways according to their own internal logic” (Clingerman et al. 2013, 4). By exploring (some of) the tensions and ambiguities revealed in ecogenomics discourse, I not only wish to clarify what is at stake in this particular field of research, but also to shed light on the ecotechnological turn in a more general sense. In addition to the analysis of the above-mentioned sources, I interviewed several of the key players in the ecological genomics field. These interviews were designed as semi-structured philosophical conversations, in which I acted as a ‘necessary irritant’ – or, to use the more gentle words of one of my interviewees, as a ‘moral critic’ (Van Straalen, interview, February 2009). The interviews helped me to clarify the tensions and ambiguities that remained hidden in the more ‘official’ presentations of ecological genomics. Moreover, to improve my understanding of ecological genomics practices, I visited various labs and witnessed how research data are integrated in specialised databases. It is important to mention that studying these practices has never been a goal in itself, but has always been a means to clarify ecological genomics discourse.

Secondly, I will explore how the ecotechnological turn has been addressed in philosophical discourse. How have (contemporary) environmental thinkers reflected on the kinds of promises and tensions at the heart of ecological genomics and other ecotechnologies? How can these reflections help us to interpret the ecotechnological turn? Many philosophers – especially in the fields of environmental philosophy and philosophy of technology – have reflected on the relationship between science and the ecological crisis. I will ‘zoom in’ on the work of a number of these thinkers, notably the Australian eco-feminist Val Plumwood (1939-2008), and the German philosopher and cultural theorist Peter Sloterdijk (1947). In her last book *Environmental Culture: the Ecological Crisis of Reason* (2002), Plumwood explores the origins and cultural illusions behind the ecological crisis. She understands the degradation of the Earth’s ecosystems as a result of western culture’s dualistic conception of reality. We human beings situate ourselves not only outside, but also *above* nature. Thus, we have developed conceptions of ourselves as “belonging to a superior sphere apart, a rational sphere of exclusively ‘human’ ethics, technology and culture dissociated from nature and ecology” (Plumwood 2002, 100). This dualistic framework has also affected our view of the relationship between science and the ecological crisis: we are inclined “to overestimate and overvalue our own technological control and to vastly underestimate [science’s] potential for negative impacts on us and on the more-than-human world”
Studying the work of environmental thinkers can help us to critically assess the claims and promises at the core of ecological genomics and other ecotechnologies. However, philosophical reflections on ecotechnology remain to a large extent external, and provide a rather general assessment of the turn towards a more ‘natural’ natural science. Therefore, the focus on a case study (in my case: ecological genomics) will add value to the debate in the sense that it will allow me to elaborate the idea of an ecotechnological turn in more detail. As ‘ecotechnology in practice’, ecological genomics gives us a fuller picture of the issues at stake.

1.7 The core of this thesis: four papers

The core of this thesis consists of four papers, which, although clearly connected, can also be considered as independent pieces of work, concentrating on different tensions and addressing slightly different audiences. Whereas the first two papers clarify the most significant tensions within the ecological genomics field, the third and fourth paper offer a more general reflection on how the relationship between humans, technology and nature has changed as a result of recent developments in the life sciences. The connection between the four papers can be made in a number of ways. In the above, I already explained that all four papers, in one way or another, combine ecological genomics discourse with philosophical reflections. Moreover, each paper focusses on one or more of the promises at the core of ecological genomics and other instances of ecotechnology. Furthermore, all papers concentrate on a tension between ‘old’ (i.e. ‘traditional) and ‘new’ (i.e ‘ecotechnological’) approaches to nature. In the next two subsections, I will show the connection between the four papers based on (a) the promises they deal with; and on (b) the way they reflect a tension between ‘old’ and ‘new’ approaches to nature.
Ecological genomics is presented as a field of research that promises to bridge the gap between ecological and genomic investigations (promise 1). In the first paper, I will reflect on this promise by exploring how ecology and genomics are integrated in the two approaches that dominate this field today: the organism-centred approach, concentrating on (individual) model organisms, and the metagenomic approach, focusing on entire microbial communities composed of a variety of species.

In the second paper, I will make a start with exploring the ambivalence between the societal and ecological promises in ecological genomics. Ecogenomicists claim that the field will serve human needs (promise 2), while at the same time respecting the integrity of ecosystems (promise 3). However, the desire to exploit the field’s potential for useful applications threatens to undermine the ecological promise. ‘Zooming in’ on a case from the Dutch ecogenomics field, I will show how the tension between the societal and ecological promises reveals itself in a disagreement about the field’s (future) research direction.

In the third paper, co-authored with Martin Drenthen, we will again look at the tension between the societal and ecological promises. Yet, instead of merely concentrating on ecological genomics discourse, we will explore how this tension is expressed in two ‘narratives of ecotechnology’: the treasure quest narrative, used by metagenomicists to draw attention to the wealth of products yet to be discovered in the soil, and the teacher-student narrative, used by biomimics to underline that in order to do justice to nature’s own creative processes, we should “view nature as a source of ideas instead of goods.”

In the fourth paper, I will explore how the philosophical writings of Peter Sloterdijk can be used as a starting point to reflect on a tension that has not yet been fully addressed in the previous papers. Sloterdijk assumes that an increased understanding of the dynamics of nature (promise 1) will, more or less in and of itself, lead to an attitude towards nature that no longer strives for mastery and domination (promise 3). I will problematise this assumption, using examples from the ecogenomics field as an illustration.

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I agree with Val Plumwood that "the problems of representing another [...] species communication [...] pale before the enormity of failing to represent them at all, or of representing them as non-communicative and non-intentional beings. This is an incomparably greater failing" (2002, 61).

1.8 Slippery terms

In this thesis, I will use a number of terms the meaning of which is notoriously fluid, such as ‘nature’, ‘ecology’, and ‘sustainability’, to name the most prominent ones. Probably the most complicated of these terms is ‘nature’, a term which is as ‘impossible’ as it is ‘inevitable’. As Sarah Parry and John Dupré argue, “Nature continues to be one of the slipperiest, most complex words in the English language. [...] The topic of nature is vast, and the quantity of books and papers already penned on it is inspiring and daunting in equal measure” (2010, 6-7, cf. Clingerman et al. 2013, 6). In this thesis, I will use the above-mentioned terms as I encountered them in ecological genomics discourse. This implies that they will be used in a rather ‘loose’ way, not as theoretically well-founded concepts. A few clarifying remarks are nevertheless appropriate.

Nature

Western culture traditionally defines nature in dualistic terms, i.e. as that which is somehow separate from humanity (nature versus culture, society, technology, etc.). Throughout this thesis, phrases are used that (seem to) endorse such a dualistic conception of nature. However, such phrases usually are part of ecogenomics discourse as analysed in this thesis. To the extent that this discourse is ‘read aloud’, its phrasing of the relationship between nature and humanity is taken up as well. Personally, however, I support an inclusive conception of nature, “one that accommodates both the human and the nonhuman components of the greater life system, without collapsing the distinction between them” (Mathews 2011, 365-366). Therefore, whenever I take the floor myself, whenever the analysis of contemporary discourse gives way to formulating an assessment of my own, a more inclusive conception of nature will be used as a point of departure.

Ecology

In ecological genomics discourse, the term ‘ecology’ is primarily used to refer to the scientific discipline of ecology, i.e. the study of interactions between organisms and their environments (their οἶκος). However, sometimes the term is used in an idealised sense, “connoting something quite different from its academic namesake” (Evernden 1993, 5). Used in this second sense, the term ecology refers to a particular world-view or way of life. This is for example expressed by Edward Goldsmith, who distinguishes two fundamental principles that necessarily underlie an ecological world-view: “The living world or ecosphere is the basic source of all benefits and hence of all wealth [...]”, but will only dispense these

9 Holmes Rolston has also reflected on the complexity of the term ‘nature’: “Nature is an absolutely indispensable English word, but there are few others with such a tapestry of meanings. In this respect it is like other monumental words round which life turns to such a high degree that we often capitalize them – Freedom, the Good, the Right, Beauty, Truth, God, my Country, Democracy, the Church – words that demand an ethical response, words that we cannot altogether and at once keep in logical perspective, but can only attack piecemeal, always reasoning out of the personal backing of our responsive perceptual experience” (Rolston 1979, 9).

10 I agree with Val Plumwood that “[t]he problems of representing another [...] species communication [...] pale before the enormity of failing to represent them at all, or of representing them as non-communicative and non-intentional beings. This is an incomparably greater failing” (2002, 61).
benefits to us if we preserve its critical order” (1998, xv). Moreover, “the overarching goal of this behavior pattern of an ecological society must be to preserve the critical order of the natural world or of the cosmos that encompasses it” (Idem, xv; cf. Bookchin 1982; Zweers 2000).

Finally, we can also distinguish a third use of the ‘eco’ in ecological genomics, which can be found among those researchers using the abbreviated version ‘ecogenomics’. Some of them actually, without irony, think the prefix ‘eco’ stands for economy instead of ecology, in the sense of the economic benefits expected to be brought about by the field (Mark Bailey, interview, May 2010). Thus, some users of the term ecogenomics fail to see its ecological meaning entirely!

**Sustainability**

Although ‘sustainability’ has become a prominent term in academic and public discussions, there is not much agreement on its exact definition. One could say that the term has been so successful and has been used in so many contexts and in so many ways, that its content has eroded. In the most common definitions – for instance the one given by the Brundtland Commission’s acclaimed report *Our Common Future* (WCED 1987) – the term ‘sustainability’ refers to three fundamental relationships of the human being: “The relation with other contemporaries, with nature, and with past and future generations.” In ecological genomics discourse, the term ‘sustainability’ is used mainly to specifically refer to one of these three relationships, namely the one between humans and nature.

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11 This economic use of the term ecogenomics does not represent Bailey’s own vision.
12 The Brundtland Report defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987, 1).
14 Sometimes, the meaning of the term ‘sustainability’ in ecogenomics discourse seems to be interchangeable with ‘nature-friendliness’ (in Dutch: ‘natuurvriendelijkheid’).

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15 An important contribution in this direction has already been made by Van Straalen and Roelofs (2006), among others.
meaningful order. For instance, it might further develop the image of land as a 'collective organism', as proposed by Aldo Leopold.

The case study in Chapter 3 reveals how ‘tainted’ terminology may function as a catalyst to reveal the normative dimensions of ecogenomicists’ – and other ecotechnologists’ – conceptions of nature. In Chapter 4 (co-authored by Martin Drenthen), the normativity hidden in particular concepts and phrases will be explored in more detail. To illustrate how ecotechnologies can be distinguished from more traditional approaches to nature, scientists make use of different narrative structures, metaphors, and images. With these narrative self-presentations, they want to clarify and legitimise their research activities. This chapter concentrates on two ‘narratives of ecotechnology’ in order to assess how the ecotechnological turn is reflected in the imagery used by scientists of the ‘new style’: the treasure quest narrative, used by metagenomicists, and the teacher-student narrative, used in the ecotechnological practice of biomimicry. These two narrative self-presentations are used because they supposedly provide sympathetic models with positive connotations only. Yet, their scientific users tend to underestimate the complex, multi-layered character of the broader cultural narratives to which they refer and from which they derive their motivational force. We will show the ambivalence of both the treasure quest and teacher-student narratives by using well-known movies as illustrations. As an example of an archetypical moral narrative about treasure hunting, we will look at Steven Spielberg’s first Indiana Jones movie, Raiders of the Lost Ark (1981). To illustrate what is at stake in the teacher-student narrative, we believe that the theme of the sorcerer’s apprentice is the most influential. We chose to explore not so much Goethe’s classic poem, but rather its much more popular 20th century depiction in Walt Disney’s The Sorcerer’s Apprentice (1940).

In Chapter 5, I will put ecological genomics discourse aside for a moment, to explore how the ecotechnological turn has been addressed in the philosophical writings of Peter Sloterdijk. Using Sloterdijk’s distinction between traditional allotechnologies and the newly emerging
homeotechnologies as a starting point, I will critically reflect on the potential of ecotechnology to bring about a new, more sustainable relationship between humans, technology and nature. Sloterdijk uses three concepts to describe the revolutionary nature of homeotechnology. First, he claims that homeotechnology is “founded on an imitatio naturae” (Sloterdijk & Heinrichs 2006, 329). Second, Sloterdijk characterises homeotechnology as a “non-dominant form of operativity” (Sloterdijk 2001, 227). The third concept related to homeotechnology is co-operation (Idem, 228). Although I appreciate the evocative and inspiring manner in which Sloterdijk unfolds what homeotechnology could unleash, I will argue that his reflections are based on a series of problematic assumptions. First of all, the conviction that we are able to copy even nature’s most intricate and refined processes appears to be quite hubristic. Even if we assume that at some point, our understanding of nature’s modus operandi is sufficiently developed to imitate these processes, this does not as a matter of course preclude domination; it opens up new prospects for exploitation, for instance by means of genetic manipulation and ‘nature mining’. Moreover, as today’s technoscience obscures the classical distinction between ‘biomachines’ and ‘manmade machines’, this exploitation runs the risk of becoming increasingly subtle and cloaked. Thus, homeotechnology may result in strengthening our control over nature even on a molecular level. I will conclude chapter 5 by arguing that the question of whether homeotechnology will contribute to a more sustainable future, largely depends on the broader framework within which it is implemented. Building on the work of Val Plumwood, I will present some preliminary thoughts on the “political and social circumstances [in which homeotechnological] solutions could be stable and effective” (Plumwood 2002, 8).

In the final Chapter 6, I will present the main conclusions of this thesis, starting with a review of the promises contained in ecological genomics discourse. I will discuss that, despite the promise of redefining the bond between humans, technology and nature, ecogenomics still strongly reflects an instrumental outlook on nature. Next, I will show that ecogenomics discourse also reveals a different, more humble story of nature, albeit as an undercurrent. Finally, building on the work of Val Plumwood, this thesis closes with the consideration that, to protect ecological genomics and other ecotechnologies from becoming spokesmen of an instrumental and reductionist mode of thought, they must be integrated in ‘democratic’ forms of science which include the entire “material and sensory world of nature” (Plumwood 2002, 47).
Chapter 2
Bridging the lab-field divide?
The ‘eco’ in ecological genomics
Since the beginning of the twentieth century, our understanding of the role of genes in living systems has evolved rapidly. The “century of the gene” (Keller 2000) started in 1900 with the rediscovery of Gregor Mendel’s work on plant hybridization by Hugo de Vries, Carl Correns, and Erich von Tschermak, and ended with the Human Genome Project (HGP), devoted to the identification of all the genes on the human genome. After the completion of the HGP in 2003, the ‘genomics revolution’ expanded beyond genetics, and started to influence many other areas of the life sciences, including ecology (Van Straalen & Roelofs 2006).

In this paper, I will focus on ecological genomics, an area of research that seeks to incorporate techniques and approaches originating from genomics into the context of ecology. As field-based ecological research and laboratory-based molecular investigations traditionally occupied different areas within the biological sciences, this merging of ecology and genomics promises to “revolutionize our understanding of a broad range of biological phenomena” (Ungerer et al. 2008, 178). The focal point of this paper will be to explore how ecology and genomics are integrated in the two different approaches that currently dominate ecological genomics: the organism-centred and the metagenomic approaches. Whereas the first

2.1 Introduction

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16 This chapter has been published in History and Philosophy of the Life Sciences (2013), Volume 35, Number 4, pp. 577-598. The headings have been numbered to fit the lay-out of the thesis. I would like to convey my special thanks to Hub Zwart, Martin Drenthen, Nico van Straalen, Staffan Mueller-Wille, and two anonymous reviewers for their valuable comments that helped to improve this text.
field of emerging research, as well as to clarify its methodological and epistemological challenges. As the field is still in its infancy, such an endeavour will be relevant not only for involved researchers, but also for policy makers and other users of the kind of knowledge ecological genomics is producing. I will start with a section that describes how the most important components of the field were set up by Feder and Mitchell-Olds in their paper “Ecological and Evolutionary Functional Genomics” (2003). Next, I will explore how ecological genomics seeks to bridge the gap between ecological and genomic research, as its very name suggests it will. Third, I will analyse how ecology and genomics are integrated in the organism-centred approach on the one hand, and the metagenomic approach on the other.

2.2 The inception of ecological genomics

In August 2003, Martin Feder and Thomas Mitchell-Olds published the article “Evolutionary and Ecological Functional Genomics” [EEFG] in Nature Reviews Genetics. This publication laid the ground for a new field of research. The authors claimed that “a unique combination of disciplines is emerging – evolutionary and ecological functional genomics – which focuses on the genes that affect ecological success and evolutionary fitness in natural environments and populations.” The goal of EEFG is to understand how wild-type organisms can flourish in nature in spite of severe challenges from their biotic and abiotic environments. This can be accomplished by a detailed study of “the biological mechanisms that influence or underlie ecologically important traits.”

By exploring the latest developments within ecological genomics, this paper seeks to contribute to a better understanding of this intriguing approach seeks to improve our understanding of ecosystem functioning by focussing on the level of the individual (model) organism, the second concentrates on (the metagene of) entire microbial communities composed of a variety of species. I will argue that the organism-centred and metagenomic approaches have already made notable progress towards closing the gap between ecology and genomics. Thanks to the introduction of next-generation sequencing methodology, which became widely available in 2007 (Evanko & Rusk 2008), the organism-centred approach does not need to stick to classical model organisms like Arabidopsis and Drosophila anymore. Instead, it now proves to be able to apply genomic tools to ecologically interesting species, i.e. species that provide insight in critical ecological interactions, such as amphibians, reptiles and birds. The metagenomic approach has found other ways to give ecology a more prominent place in its investigations. It has revolutionised the field of microbiology (the field from which it originates) by enabling the study of microbial populations in their native habitats. Thus, instead of studying communities of microorganisms under controlled laboratory settings, metagenomics allows us to explore them under nature’s own conditions. The organism-centred and metagenomic approaches, however, still seem to be “orientated more towards ‘genomics’ than towards ‘eco’” (Ouborg & Vriezen 2007, 14). This applies especially to the organism-centred approach, which continues to study its new ecological models in the artificial environment of the laboratory. Moreover, in understanding ecosystem processes, the organism-centred and metagenomic approaches employ a gene-centred perspective. DNA is regarded as the main determining factor, and not as “just one of the many functioning components of a larger interacting molecular system” (Barnes & Dupré 2008, 73).

In principle, the metagenomic approach could also be applied to identify eukaryote species assemblages (cf. Chariton et al. 2010). This type of research, however, is not (yet) dominant in ecological genomics.
A number of key scientists refer to Feder and Mitchell-Olds’s paper as the manifesto of a new research area, generally referred to as ‘ecological genomics’ – sometimes abbreviated to ‘eco-genomics’ or ‘ecogenomics’ (Ouborg & Vrizen 2007, 9; Maphosa et al. 2010, 308, Gobler et al. 2011, 4352). For instance, in An Introduction to Ecological Genomics (2006), the first textbook entirely dedicated to this field, Van Straalen and Roelofs claim that in the ecological arena, “the interaction between genomics and ecology has led to a new field of research, evolutionary and ecological functional genomics” (Van Straalen & Roelofs 2006, 1 – authors’ emphasis). Renn and Siemens also refer to Feder and Mitchell-Olds’s paper as the birth of ecological genomics: “Inception of the field [i.e. ecological genomics] was formalized in a publication by Feder & Mitchell-Olds (2003) with the descriptive title ‘Evolutionary and Ecological Functional Genomics’” (Renn & Siemens 2010, 3025).

Why was the publication by Feder and Mitchell-Olds considered such a crucial moment in the history of ecological genomics? In an interview, Van Straalen explained that in this paper, genomics was directly linked to ecology for the first time (Interview, May 2010). Strictly speaking, this singling out of Feder and Mitchell-Olds as the founding fathers of the new field may be called into question, as there are some earlier examples. Notably, the Israeli biology professor Eviatar Nevo published a plea for an integrated ecological genomics discipline as early as 1998. Nevo explicitly gave the proposed synthesis the name ‘ecological genomics’. He introduced the concept in an article entitled “Molecular evolution and ecological stress at global, regional and local scales: The Israeli perspective” (1998), which appeared in the Journal of Experimental Zoology. Three years later, he further elaborated his views in an article that was published in Proceedings of the National Academy of Sciences of the United States of America (PNAS).

Nevo presents ecological genomics as a new approach, building on ecological genetics, a discipline going back to the 1960s. It was founded by the English biologist Edmund Brisco Ford, who aimed to shed light on the reciprocal relationships between organisms and their environment. Ford and colleagues tried to accomplish this by studying phenotypic evolution in wild populations. Nevo argues that thanks to the genomic revolution, evolutionary processes can now be studied in much greater detail: “Ecological genetics advanced by Ford […] could now develop into the new science of ecological genomics, interacting with comparative structural and functional genomics” (Nevo 2001, 6239).

So actually, Nevo was the first to use the term ecological genomics in an academic publication, preceding Feder and Mitchell-Olds’s paper by five years. He explained his motivation for introducing this term as follows: “I did not see it elsewhere and used it because I very much believe in the interdisciplinarity of science and all my work has shown that the evolutionary process is dependent on the linkage between ecology and genetics or now between ecology and genomics” (E-mail correspondence, November 2010). However, although Nevo’s interpretation is very similar to the view presented by Feder and Mitchell-Olds, the real breakthrough in ecological genomics only came after the publication by the latter two authors.

One of the reasons for Feder and Mitchell-Olds’s success might be that they were able to gather a large research network around them. This network was formalised by the 2003 Gordon Research Conference on Evolutionary and Ecological Functional Genomics, which was intended to be the “conference of record” for the EEFG community. The importance of Feder and Mitchell-Olds’s publication is also reflected in the following statements. Loretta

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18 Sometimes, the field is also referred to as ‘environmental genomics’ (e.g. Van Straalen & Feder 2011, 3). The latter term, however, is more frequently used as a synonym for metagenomics (e.g. Venter et al. 2004, 1; Quince et al. 2011, 1).

19 As ecological genomics has evolved very fast since 2006, the first edition of Van Straalen and Roelofs’s textbook was followed by a second edition in 2012, describing the latest developments in the field. For chronological purposes I will refer to the first edition.

20 In spite of the fact that Nevo is no stranger in the ecological genomics community, neither Feder and Mitchell-Olds (2003), nor Van Straalen and Roelofs (2006) refer to his publications.
Johnson, co-director of the Ecological Genomics Institute (EcoGen) at Kansas State University, explained to me that “everyone was very much influenced by the seminar paper by Feder and Mitchell-Olds (2003) in *Nature Reviews Genetics*” (E-mail correspondence, January 2011). Ouborg and Vriezen go even further, claiming Feder and Mitchell-Olds were the first to use the exact term eco-genomics: “This approach, which has been named ‘eco-genomics’ (Feder and Mitchell-Olds 2003), integrates the disciplines of ecology and molecular biology” (Ouborg & Vriezen 2007, 9).²³

Feder and Mitchell-Olds themselves, however, neither used the terms ecogenomics nor ecological genomics in their 2003 paper, but only the more extended version EEFG. What is more, their main motivation for writing “Evolutionary and Ecological Functional Genomics” was not to introduce a new research area, but to emphasise the role of evolution in ecological processes. In an interview, Feder argued that in his experience, “ecologists are sometimes not strongly evolutionary. [...] the notion of time is not extremely important to some of them. There is time in the sense of community succession, but the idea that the species themselves change over time in the process of evolution is not one that they worry about a great deal” (Interview, May 2010).

Feder and Mitchell-Olds stress that, in order to understand wild type organisms and their evolution, an interdisciplinary approach is required: “The molecular tools and functional understanding that are required to accomplish the goals of the field are beyond the capacity of any single investigator, which necessitates sustained interactions among research communities” (Feder & Mitchell-Olds 2003, 649). A similar message can be found in Feder’s proposal to the National Science Foundation, in which he explains how each of the four components of EEFG are necessary to achieve the goals of the field. As EEFG seeks “to understand the interaction of genes, function, environment and time in a rigorous, comprehensive sense, corresponding investigations will need to include genetics/genomics, function, ecology, and evolutionary biology” (Feder 2000, 1).

### 2.3 Crossing the lab-field border

It is interesting to note that from the very beginning, readers of Feder and Mitchell-Olds’s paper paid particular attention to two of the four components that shape EEFG: ecology and genomics. This becomes apparent in their definitions of the field. Van Straalen and Roelofs define ecological genomics as “a scientific discipline that studies the structure and functioning of a genome with the aim of understanding the relationship between the organism and its biotic and abiotic environments” (Van Straalen & Roelofs 2006, 1). Ungerer, Johnson and Herman give a similar definition: “We define ecological genomics as an integrative field of study that seeks to understand the genetic mechanisms underlying responses of organisms to their natural environment” (Ungerer et al. 2008, 178). Based on these definitions, it might appear that ecological genomics merely applies a new tool – i.e. genomics – for the purpose of analysing fundamental ecological questions. Van Straalen and Roelofs nevertheless emphasise that “the merging of genomics with ecology includes more than the incorporation of a toolbox, because with the new technology new scientific questions emerge and existing questions in ecology can be answered in a way that was not considered before” (Van Straalen & Roelofs 2006, 1). Ungerer and colleagues have great expectations of the field as well: “Such an integration of fields […] will revolutionize our understanding of a broad range of biological
phenomena” (Ungerer et al. 2008, 178).

Why are these scientists so convinced that the merging of genomics and ecology will be a great leap forward? Ungerer and colleagues answer this question as follows:

“Ecological and laboratory-based genetic/genomic investigations traditionally have occupied different areas of the biological sciences […]. With a few notable exceptions, research programs are generally positioned in one domain or the other, but do not regularly cross the boundary that separates these disciplines by utilizing the tools and approaches of both” (Ungerer et al. 2008, 178).

EEFG, and consequently ecological genomics, seek to integrate these disciplines by incorporating techniques and approaches originating from genomic research in an ecological context. Ouborg and Vriezen have a similar view of the revolutionary potential of ecological genomics. Ecology and molecular biology, they stress, are rooted in different research traditions:

“Molecular biologists prefer to work in controlled environments and with homogeneous well-defined genetic material, aiming to remove as much variation as possible. For ecologists, environmental and genotypic variation is their core business, which they try to incorporate in experimental designs rather than controlling for it” (Ouborg & Vriezen 2007, 13).

Although Ouborg and Vriezen present ecological genomics as a very promising field, they emphasise that achieving a true synthesis between ecological and molecular investigations will prove to be a major challenge: “The challenge to ecogenomics is to fine-tune experimental designs of ecology and molecular biology in order to accomplish true integration of the data that originate from these two fields” (Idem, 13).

The book *Landscapes and Labscapes* (2002) by the historian and sociologist of science Robert Kohler sheds light on the gap between ecological and molecular investigations. In this book, he explores the cultural differences between laboratory and field science from the 1890s to the 1950s by concentrating on the subset of field disciplines that were most strongly influenced by lab culture in those days: ecology and evolution. Although the book was written before ecological genomics had become a research field of international prominence, Kohler’s exploration helps us to understand the cultural gap between the two research traditions that are at the core of ecological genomics. According to Kohler, laboratory and field work are marked by various differences. Firstly, the notion of ‘place’ figures differently in lab and field practices. Laboratory workers try to eliminate the element of place from their experiments: “It is precisely the stripped-down simplicity and invariability of labs – their *placelessness* – that gives them their credibility.” By contrast, field biologists consider “places [to be] as much the object of their work as the creatures that live in them. […] Plants and animals are elements of natural environments, along with topography, habitat, and weather: they are not mere passive guests as they are in labs, but actively alter their environments.” A second difference between lab and field is that the former are pre-eminently controlled environments. On the contrary, natural places are particular and variable places, “each the result of a unique local history, never the same from one moment to the next, unpredictable, unrepeatable, beyond human control” (Kohler 2002, 6–7; my emphases). In the next section, I will apply Kohler’s insights to the case of ecological genomics.

### 2.4 Overcoming reductionism

The difference between laboratory (molecular) and field (ecological) research is sometimes described as the difference between a *reductionist* and a *holistic* approach (Bergandi & Blandin 1998; Gierer
2002; Zwart 2007), Zwart draws a distinction between a strong and weak version of reductionism. According to the strong version (also referred to as 'ontological reductionism'), “all phenomena in nature can ultimately be reduced to a limited number of causal units [...]. These primal causal units are regarded as determinants of everything else” (Zwart 2007, 192). Representatives of the weak version of reductionism do not actually believe that the system as a whole can be explained on the basis of a limited set of mono-causal relationships. They see reductionism as a methodological requirement. In the context of laboratory research, it is impossible to do justice to the complexity of the real world. The number of factors that can be meaningfully studied is limited. “Once the relationships between these factors have been established, researchers will try to extrapolate their research findings to the real world, in the expectation that, out there, things will prove to be much more complicated” (Idem, 193). Holists maintain that “breaking nature down into its atomistic parts cannot result in a true understanding of the whole” (Worster 1994, 22). The whole of nature is more than, or something other than, the sum of its parts. As ecologists frequently argue that “special qualities emerge out of interactions and collectives” (Idem, 22), ecology is often seen as one of the exemplary approaches to holism. This applies especially to ecosystem ecology, as this field emphasises “the interconnections among things and events sometimes distant in space and time” (Burns 1990, 193).

In the preceding section, I explained that ecological genomics aims to reconcile the experimental languages of ecologists and molecular biologists. Using the concepts set out in the above, it could be argued that the holistic and reductionist research cultures of ecology and molecular biology must learn to speak a common language. Van Straalen and Roelofs, however, seem to suggest that in the research field of ecological genomics, this confusion of tongues has already been overcome; not only ecology, but genomics, too, goes against the deterministic, reductionist approach of laboratory culture. Van Straalen and Roelofs explain that genomics allows us to study the genome and its products as a unitary whole; it is based on the observation that “the impact of one gene on the phenotype can only be understood in the context of the expression of several other genes or, in fact, of all other genes in the genome, plus their products, metabolites, cell structures, and all the interactions between them” (Van Straalen & Roelofs 2006, 3). The authors argue that, by integrating ecological and genomic investigations, it has become possible to conduct a detailed study of ecosystem functioning both on the macro- and micro-level. Thus, ecological genomics enables us to explore phenotypic biodiversity as well as genome diversity: “With this new discipline, ecology is enriched by genomics technology and genomics is enriched by ecological questioning and evolutionary views” (Idem, 3). In a focus issue on ecological genomics of the journal Environmental Science and Technology, Van Straalen and Feder explicitly call the genomic approach holistic. “The typical approach of genomics”, they claim, “is to look upon the organism as a unitary whole, that is, to try and analyse as many genes as possible [...]. Such a holistic view of organism function has been made possible by technological and computational advances” (Van Straalen & Feder 2012, 4).

How can we interpret these claims? Should we conclude that ecological genomics has already succeeded in bridging the gap between ecological and molecular investigations? All in all, it appears to be too early for such a statement. It is true that, compared to traditional genetics, genomics is much more aware of “any effects elsewhere in the genome, outside the system under study” (Van Straalen & Roelofs 2006, 3). As Zwart argues, whereas classical genetics focussed on a limited number of genes, “genomics allows us to simultaneously study the function of all the genes on the genome of an organism” (Zwart 2007, 193 – author’s emphasis). Genomics, however, does not entirely escape reductionism. First, it is important to keep in mind that the study and analysis of complex relationships still takes place within a laboratory setting. Genomicists assume that, thanks to the availability of new research tools (high throughput analysis, bioinformatics, computational biology, micro-array research), laboratory experiments are consistent with actual ecological processes. Second, in understanding the system
as a whole, DNA is still considered the main determining factor, instead of being “reconceptualised as just one of the many functioning components of a larger interacting molecular system” (Barnes & Dupré 2008, 73).

2.5 Two approaches in ecological genomics

Earlier, I explained that ecological genomics involves a number of different research communities. As Ungerer and colleagues argue, a deeper understanding of the genetic mechanisms underlying responses of organisms to their natural environments requires a multidisciplinary approach, “combining organismal analyses with molecular genetics and genomics, laboratory experiments with field studies and all within an ecologically relevant framework” (Ungerer et al. 2008, 187). Currently, the field is dominated by two different approaches, one focussing on the level of the individual organism, the other on entire ecosystems (Feder & Mitchell-Olds 2003; Ungerer et al. 2008; Mitchell-Olds et al. 2008). Ungerer and colleagues describe the difference between both approaches as follows:

“One goal of ecological genomic studies is to understand the genetic mechanisms underlying responses of organisms to their natural environments. This question typically is focused at the level of the organism. Another goal of ecological genomic research is to understand how genomes interact at higher levels of organization, for example, is there a ‘community genome’ and if so, can we understand how it functions” (Ungerer et al. 2008, 181 – my emphasis).

The ‘organism-centred approach’ (cf. Marco 2010, preface) seeks to improve our understanding of critical ecological interactions by focussing on the level of individual organisms, for instance by exploring how organisms respond to environmental change and how populations can adapt to environmental toxicants (Van Straalen & Feder, 2012). As a rule, the organism-centred approach is organised around classical laboratory-based model organisms, i.e. organisms with well-characterised gene expression patterns and large research networks around them. Examples of such model species are the plant Arabidopsis thaliana, the fruit fly Drosophila melanogaster, and the nematode Caenorhabditis elegans (Jackson et al. 2002, 409; Van Straalen & Roelofs 2006, 4; Maher 2009, 695; Ankeny & Leonelli 2011, 316). By exposing the model to different environmental conditions (humidity, drought, etc.), the genes and gene functions that matter most in a given ecological interaction are identified (Ungerer et al. 2008). According to Feder, model organism studies are based on the assumption that such studies “can provide insight into the biology of some or many (if not most or even all) other organisms” (Feder 2006, 163 – author’s emphasis). Recent advances in genomics have validated this assumption: “… large amounts of the genomes sequenced to date are clearly homologous among organisms” (Idem, 163). Thanks to these homologies, the data and theories obtained from the models are expected to also be applicable to ecologically interesting species (Aparicio et al. 2002).

The ‘metagenomic approach’ does not concentrate on the level of the individual organism, but aims to study ecosystems as a whole; the starting material is not derived from a single species, but from many different organisms (Dale et al. 2012). This approach is also referred to as environmental genomics (Venter et al. 2004; Mitchell-Olds et al. 2008), community genomics (Dupré & O’Malley 2007; Xu et al. 2011). Kloe et al. (2011) refer to the organism-centred approach as ‘model organism ecogenomics’. In the last few years, genomic tools have increasingly been applied to non-model species, and the expression ‘model organism ecogenomics’ thus appears to be too narrow to cover all research conducted under this label. That is why I prefer the term ‘organism-centred approach’.

23 Barnes and Dupré do not make it explicit whether or not they share this view of genomics as a (partly) reductionist approach; their aim is to reflect on the implications of different interpretations of genomics.
2.6 The organism-centred approach: to model or not to model?

In the preceding section, I explained that the organism-centred approach is usually organised around classical model organisms with fully sequenced genomes. As the genomes of organisms share a significant degree of homology with related species, research on model organisms is expected to provide insight into the biology of ecologically interesting species as well. The general applicability of standard model organisms in ecological genomics studies, however, needs to be critically assessed. According to Feder, the question of whether or not to use these species depends very much on the issue we want to address: "... if the underlying research question is general (e.g., Does susceptibility to environmental stress increase during development?), then standard model systems are often [...] readily applicable" (Feder 2006, 164). By contrast, "If the underlying research question is specific and species-driven (e.g., How does the fairy shrimp tolerate extreme temperatures or [high salt] concentrations early in development?), then application of standard model systems is likely to be as problematic as the phylogenetic and ecological distance between the nearest standard model and the species under investigation" (Idem, 164).

The physiologist August Krogh warned against uncritical generalisations from model systems to solve physiological problems as early as 1929. In an article entitled "The progress of Physiology", he argued that "a general physiology which can describe the essential characteristics of matter in the living state is an ideal to which we may hope that our successors may attain after many generations" (Krogh 1929, 4). He claimed that "the route by which we can strive toward the ideal is by a study of the vital functions in all their aspects throughout the myriads of organisms" (Idem, 4 – my emphasis). In 1975, Krogh’s considerations inspired the physician and biochemist Hans Krebs to formulate the August Krogh

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25 In the intermezzo following this chapter, I will draw attention to confusions brought about by differences in terminology among the various scientific communities active in the ecological genomics field.

26 Van Straalen and Roelofs (2006) also distinguish a third approach, to which they refer as ‘comparative genomics’. This approach studies the relationship between genome structure and function among different species. As comparative genomics is generally based on model organism studies, I will not treat this as a separate approach, but as part of the organism-centred approach.
principle, which assumes that for every physiological problem, there is an animal in which this problem can be most conveniently studied. Applied to ecological genomics, the principle urges us to critically reflect on the extent to which model organisms can represent ecologically important pathways, processes and structures. Jackson and colleagues are very critical in this respect. They argue that species such as Arabidopsis and Drosophila have not become models in genomics because of their ecological or evolutionary importance or their applicability to ecological questions, “but were selected on the basis of particular genetic and developmental features (e.g. clonal propagation, self-fertilization and short generation times) and for ease of growth in the laboratory” (Jackson et al. 2002, 409). Ouborg and Vriezen express the same criticism: “These species have become model species of genomics because of their suitable properties: small genomes, short generation times and easy maintenance in the glasshouse. They are not chosen because of their specific ecology, and they certainly do not cover all life-history strategies and habitats” (Ouborg & Vriezen 2007, 12; cf. Van Straalen & Feder 2011, 3).

What makes a species a suitable model for ecological genomics? Van Straalen and Roelofs come up with three criteria. Number one, “The new range of models should embrace diverse phylogenetic lineages, varying in their physiology and life-history strategy. […] Considering the diversity of life histories, species differing in their mode of reproduction and dispersal capacity should be chosen; for example, hermaphroditism versus gonochorism, parthenogenesis versus bisexual reproduction, etc.”

As a second criteria, species have to take part in critical ecological interactions, for instance “mycorrhizae, nitrogen-fixing symbionts, pollinators, natural enemies of pests, parasites, etc.” And finally, the new ‘ecogenomic’ models should be suitable for field research, since “[n]ot all species lend themselves to studies of behaviour, foraging strategy, habitat choice, population size, age structure, dispersal, or migration in the field.” Examples of species that fit these criteria are reptiles, amphibians, molluscs, annelids, birds and non-insect arthropods. For these organisms, however, adequate genomics resources (funding, research programmes, research consortia) are not always available. As Van Straalen and Roelofs argue, “many popular ecological models have a poorly characterized genome and lack a large community of investigators” (Van Straalen & Roelofs 2006, 8-9; cf. Jackson et al. 2002).

Ecological genomicsists are thus faced with a dilemma: “Should the ecology of selected organisms that may not be very representative be studied, or should the genomic capabilities of more ecologically interesting taxa be developed?” (Ungerer et al. 2008, 181). Feder and Mitchell-Olds describe this model versus non-model question as a “near-philosophical debate, the extremes of which are whether to make the customary biomedical model organisms do ‘double duty’ as model wild organisms, for which they are often not well suited, or to forego the advantages of massive community support to optimize the insights that are emerging from the study of non-classical model organisms” (Feder & Mitchell-Olds 2003, 654).

### 2.7 New models for the organism-centred approach

In the editorial Evolutionary and ecological functional genomics (2008), building on the 2003 article with the same title, Mitchell-Olds and colleagues argue that thanks to “changing technology and decreasing costs, the time is approaching when genomic tools can be applied to diverse non-model species, characterizing new levels of complexity in natural systems and enabling tests of fundamental hypotheses in ecology and evolution” (Mitchell-Olds et al. 2008, 101). Ungerer and colleagues have similar expectations for the future: “Genomic resources are now also being developed for several species with rich histories
of ecological investigation; these species will likely emerge as the new ‘models’ for ecological genomics research” (Ungerer et al. 2008, 182). According to Van Straalen, the shift from traditional model organisms to ecologically interesting species implies a qualitative change for the ecological genomics field (Interview, December 2011).

Which technological advances have facilitated this shift towards new model species? A first step was the development of DNA microarrays, first described by Schena and colleagues in 1995. By attaching a collection of microscopic DNA spots on a coated glass plate, the expression levels of large numbers of genes could be studied simultaneously. This now classical technology was subsequently joined by technologies such as quantitative RNA sequencing (RNAseq) and high-throughput quantitative polymerase chain reaction (qPCR). The real breakthrough for the organism-centred approach, however, only became possible after the introduction of next-generation sequencing methodology (NGS), which became widely available in 2007 (Evanko & Rusk 2008). According to Van Straalen and Feder, this technology has brought about a new revolution, “as the nonmodel genomes of environmental science have become as tractable as genomes of classical genetic models” (Van Straalen & Feder 2012, 3). Although Feder and Mitchell-Olds already discussed the possibility to study non-classical model organisms in 2003, it took until 2011 before the entire genome of the first real ‘ecological species’ was sequenced, namely that of the water flea *Daphnia pulex* (Van Straalen & Feder 2012). This crustacean arthropod is a keystone species of freshwater ecosystems; it is not only a principal grazer of algae, but also a primary forage for fish, and a protector of lentic inland ecosystems. As water fleas are sensitive to modern toxicants in the environment, they can be used to assess the ecological impact of environmental change (Colbourne et al. 2011).

The above shows that the organism-centred approach has recently gotten closer to crossing the boundary between ecological and genomic investigations. However, a real merging of these disciplines has not yet taken place. Rather than bringing about a marriage between ecology and genomics, the organism-centred approach currently seems to contribute more to a *genomicalisation* of ecology than to an *ecologisation* of genomics (cf. Ouborg & Vriezen 2007). First, the rise of non-classical model species does not necessarily imply the end of gene-centredness. Although the organism-centred approach promises to go “beyond making claims on gene functions in cells or individual organisms” and “to generate insight in the relationship between organisms […] and their environment” (Kloet et al. 2011, 24 – authors’ emphasis), it is mainly interested in understanding the genetic mechanisms underlying this relationship. Second, the new ecological models are still studied under laboratory rather than field conditions. Earlier, I explained that genomicists assume that, thanks to the availability of new research tools, complex organism-environment relationships can now be thoroughly studied in the lab; ecological research is thus no longer field-bound. The introduction of next-generation sequencing methodology has supported this assumption. However, a profound understanding of critical ecological interactions seems to require more than the replacement of classical model organisms by ecologically relevant species. The artificial environments created in labs lack the unpredictability and variability of natural ecosystems, even if they are studied with the ‘right’ model (cf. Kohler 2002). In the next sections, I will explore the extent to which metagenomics has succeeded in bridging the gap between ecology and genomics.

### 2.8 The metagenomic approach: the era of ecosystems biology

As mentioned before, in the nineties most microbiologists still assumed that the majority of microorganisms in a sample could be recovered by culturing them. As a result, most knowledge about microorganisms was laboratory knowledge, “attained in the unusual and unnatural circumstances of growing them optimally in artificial media in pure culture without ecological context” (Committee on Metagenomics 2007, 13).
By enabling the culture-independent analysis of microbial populations, metagenomics has revolutionised the field of microbiology in two ways. First, “it offers a window on an enormous and previously unknown world of microorganisms” (Handelsman 2007, 8). Second, as I will elaborate later on, it allows the study of microbial communities in their native habitats. Xu therefore argues that metagenomics announces a new era in biology, “that of ecosystems biology” (Xu 2010, 1 – my emphasis). Although microbiologists already started to apply culture-independent methods in the nineties, Schloss and Handelsman introduced the term ‘metagenomics’ as late as 2003. The term ‘metagenome’ – referring to the object of research – was launched by Handelsman and colleagues five years earlier in an article that appeared in Chemistry & Biology. The prefix ‘meta’ is derived from the Ancient Greek μετά, meaning to transcend, or to go beyond. In the context of metagenomics, ‘meta’ can be interpreted as follows. In its approaches and methods, metagenomics “circumvents the unculturability and genomic diversity of most microbes” (Committee on Metagenomics 2007, 13). In other words, the field transcends the technical limitations to understanding microbial diversity (O’Malley & Dupré 2010). Furthermore, the prefix ‘meta’ means that “this new science seeks to understand biology at the aggregate level, transcending the individual organism to focus on the genes in the community and how genes might influence each other’s activities in serving collective functions” (Committee on Metagenomics 2007, 13). Metagenomics thus exceeds “the limitations of a focus on individual genes and particular species, as well as the separation of organisms from environments” (O’Malley & Dupré 2010, 185).

In this paper, metagenomics has been presented as one of the two approaches that currently dominate ecological genomics research. As explained earlier, the organism-centred and metagenomic approaches both seek to improve our understanding of critical ecological interactions. The difference between these two approaches is that, whereas the first focusses on the level of the individual (model) organism, the second explores the genome of (terrestrial and aquatic) ecosystems as a whole (Ungerer et al. 2008). However, not all research conducted under the label ‘metagenomics’ is ecologically-oriented. Even though metagenomics started as a method to study the collective genomes of the soil, the term presently covers the investigation of any microbial community: it not only refers to the exploration of terrestrial or aquatic ecosystems, but for example also to the genomic analysis of the human microbiome, i.e. the community of microorganisms living in the human body (cf. Handelsman 2007; Liebert 2008). As Xu argues:

“The broad-sense metagenomics now encompasses any investigation involving the application of modern genomics techniques to the study of biological communities directly in their natural environments, bypassing the need for the isolation, the laboratory cultivation and observation of individual organisms” (Xu 2010, 1 – my emphasis).

In the context of ecological genomics, metagenomics should be understood in a more restricted or narrow sense. Here, the term refers to the exploration of microbial communities living in natural ecological niches, such as soil, water, or air. Such ecologically-oriented investigations are at the core of one of the basic experimental approaches applied by metagenomicists: the sequence-driven approach. This approach concentrates on the screening of microbial communities to reveal the overwhelming diversity of its members:

“DNA from the environment of interest is sequenced and subjected to computational analysis. The metagenomic sequences are compared to sequences deposited in publicly available databases […]. The genes are then collected into groups of similar predicted function, and the distribution of various functions and types of proteins that conduct those functions can be assessed” (Handelsman 2007, 4).
Metagenomics, however, was not only a method to learn about the contributions to the biosphere made by its uncultivable community members; “it was also designed for practical gains, such as the discovery of new genes and gene products that would lead to new medical chemistry, agricultural innovations and industrial processes” (Idem, 3-4). This more practical focus is central to the function-driven approach. Here, the DNA extracted from the environment is not sequenced, but screened for potential applications and products, such as antibiotics, vitamins and enzymes. Handelsman claims that the potentials of metagenomics are endless: “It […] promises to provide a more complete understanding of the global cycles that keep the biosphere in balance, offer clues to the basis for many diseases, lead to development of new antimicrobial therapies and present solutions to environmental and biotechnological challenges” (Idem, 8).

2.9 The ‘eco’ in metagenomics

In this final section, I will explore how ecology is integrated in, as I will call it, narrow-sense metagenomics, i.e. in ecologically-oriented metagenomic investigations. Van Straalen explains the contribution of ecology to narrow-sense metagenomics as follows: microbial DNA is not studied under controlled laboratory settings, but under nature’s own conditions (Interview, March 2009). Xu, moreover, argues that metagenomicists are aware of the fact that the artificial environments created in labs are very different from natural environments. In order to obtain critical and realistic understanding of microbes in nature, it is essential to investigate microbial populations in their native habitats (Xu 2010, 2). Because of this move out of the laboratory, metagenomics is often referred to as a holistic approach (Leveau 2007; Cubillos-Ruiz et al. 2010; Kemperman et al. 2010). Guazzaroni and colleagues, for instance, claim that the ultimate goal of metagenomics is to get “a holistic view of the functioning of [the] microbial world” (Guazzaroni et al. 2010, 56).

If we consider how metagenomics enabled the shift from laboratory-based research to the in situ exploration of microbial communities, this approach can indeed be described as holistic. Thanks to the move from lab to field, metagenomics has provided “access to environmental communities in their whole complexity” (George et al. 2010, 121). Thus, compared to classical microbiology (the field from which metagenomics originates), ecology is given a much more prominent place. Moreover, as O’Malley and Dupré point out, metagenomics urges us to reconsider the ‘one organism, one genome’ conception of organisms: whereas “life is traditionally conceived to be organized around the pivotal unit of the individual organism” (O’Malley & Dupré 2010, 189), metagenomics...
invites us to replace this ‘monogenomic’ conception by an organism- 
and species-free context.

“Despite the tendency to think of humans and other traditionally 
conceived organisms as monogenomic possessors of a unique 
genome, a metagenomic examination of any such organism reveals 
that biological success depends on multilinear and multigenomic 
cooperations. Rather than conceiving of monogenomic organisms 
as autonomous individuals, we suggest that the basis of any 
attribution of autonomy has to be functional wholeness, which is a 
product of cooperative interaction’ (Idem, 187).

When looked at from a different angle, however, the presentation 
of metagenomics as a holistic approach can be challenged: as was 
the case for the organism-centred approach, metagenomics employs 
a gene-centred perspective. In exploring environmental samples, it 
concentrates on the genetic elements available to microbial communities. 
Genes are seen as the functioning components of the microbial system 
(cf. Barnes & Dupré 2008, 73). This focus on genes is clearly expressed 
by Handelsman:

“Metagenomics presents a system-level view of microbial 
communities. Instead of studying single organisms or single 
functions, metagenomics examines the entire complement of genes 
in a community, enabling construction of a scaffold of genes and 
functions on which to build principles about community structure 
and function” (Handelsman 2007, 5).

2.10 Conclusion

The initial promise of ecological genomics was to bring about a marriage 
between ecology and genomics. In this paper, I have argued that this 
promise has only been partially fulfilled: in the marriage between ecology 
and genomics, genomics is still the dominant partner. It is not self-evident 
that we should strive for a more equal marriage between genomics and 
ecology. After all, a successful marriage does not necessarily need to be 
an equal marriage. In my view, however, it is important to keep in mind 
that the ‘genomic language’ at the core of ecological genomics tends 
to overshadow other narratives that seek to describe nature in general, 
and complex ecological processes in particular. Both the organism and 
metagenomic approaches within ecological genomics have their own 
histories that have little in common with the ecological tradition as shaped 
by Aldo Leopold, Stephen Forbes, William Ritter, Charles Adams, and 
Edward O. Wilson, to mention a few. The question of whether ecological 
genomics could try to do more justice to this powerful tradition within 
ecology is beyond the scope of this paper.

References

Genome Shotgun Assembly and Analysis of the Genome of Fugu 
Barnes B., and J. Dupré. 2008. Genomes and what to make of them. 
Chicago: The University of Chicago Press.
Béjà O. 2004. “To BAC or not to BAC: Marine ecogenomics”. Current 
Ecosystem Ecology and Landscape Ecology Clarify the Debate?” 


Intermezzo
Confusions in terminology
It is very difficult to know the nature of the wine by looking at the label on the bottle.

– Martin Feder, May 2010

In chapter 2, I argued that ecological genomics as a field of research is currently facing a major challenge: it must bring about a marriage between field-based ecological research and laboratory-based genomic investigations. In this short intermezzo, I would like to draw attention to a related challenge: as a merger of different research disciplines, ecological genomics also has to deal with the various vocabularies of the scientific communities active in this field. The research activities referred to in this thesis as ‘ecological genomics’ and ‘metagenomics’ are known under a number of different labels: environmental genomics, community genomics, population genomics, to name the most prominent ones. These labels, moreover, are interpreted in a variety of ways. For example, ‘environmental genomics’ is used both as a synonym for ecological genomics – the study of “the structure and functioning of a genome with the aim of understanding the relationship between the organism and its biotic and abiotic environment” (Van Straalen & Feder 2011, 3) – and as a synonym for metagenomics – the culture-independent analysis of microbial communities (cf. Venter et al. 2004; DeLong 2004; Mitchell-Olds et al. 2008). Adding to the confusion, the National Institute of Environmental Health Sciences (USA) has used this term to refer to an investigation of “individual susceptibility to environmental exposures”29. The goal of this study, labelled ‘the Environmental Genome Project’, was “to characterize how specific human genetic variations, or polymorphisms, contribute to environmentally induced disease susceptibility”30.


In chapter 2, we have nevertheless seen that genomics surpasses its 'molecular parent' – or aims to do so – in at least one important respect: it wants to do away with the deterministic, reductionist approach of traditional molecular biology. As “the typical approach of genomics is to look upon the organism as a unitary whole” (Van Straalen & Feder 2012, 4), Van Straalen and Feder call this approach holistic. Although I have argued that the promise of a more holistic approach – as yet – has only been partially fulfilled, I would like to suggest that the difference between molecular biology and genomics has at least some significance.

The differences in terminology described in the above are not merely symptoms of a conceptual misunderstanding; they express different ways of being-in-the-world. When the term 'ecological genomics' was introduced, it did not as yet have any defining qualities. However, “once the new name is in place, it typically, if it’s successful, will initiate a chain reaction of events in which people are attracted to it” (Feder, interview, May 2010). The new label has a performative function and is used to create new identities. Thus, by trying to define ‘ecogenomics’ and clarify the debate, various groups of scientists try to leave their mark on the discourse.

The confusion brought about by the differences in terminology became obvious during several international meetings I attended as part of my research. Notably, I observed that some of the scientists working in the metagenomics field were somewhat taken aback by the presentation of metagenomics as one of the two approaches currently dominating ecological genomics research; they seemed to be under the impression that this particular presentation failed to recognise metagenomics as a discipline in its own right. Considering the wide currency of the term ‘metagenomics’ compared to the terms ‘ecological genomics’ and ‘ecogenomics’, their reaction is not very surprising. Over the past few years, I recorded the amount of Google hits generated by the queries ‘ecogenomics’ and ‘ecological genomics’ on the one hand, and ‘metagenomics’ on the other. In June 2009, ‘metagenomics’ yielded four times as many hits as ‘ecogenomics’ and ‘ecological genomics’ together. In May 2014, ‘metagenomics’ generated even more than ten times as many hits!

A conceptual confusion of a somewhat different nature is that ecological genomics is alternately described as a merging of ecology and genomics, and ecology and molecular biology. Could this difference be dismissed as irrelevant? According to Joop Ouborg, the terms ‘molecular biology’ and ‘genomics’ are interchangeable; the latter discipline originates from the first and can hence be seen as a subdiscipline of molecular biology (Interview, March 2009). Martin Feder, moreover, argued that he did not consider it useful to draw a distinction between molecular biology and genomics. As he put it:

“A carpenter does not worry which tool is derived from another, but simply uses the tools at hand. Historically, genomics uses the toolkit of molecular biology for data production and the toolkit of computer science for data management and analysis. Like a child, [genomics] is a product of both parents, but different in its own rights rather than simply subsidiary” (E-mail correspondence, April 2010).
Chapter 3
Nature is (a) mine: Conceptions of nature in the Dutch ecogenomics community
“Have you found the secret that I have lost?”
“Yes. You and the land are one.”
– Excalibur

3.1 Introduction

“It is inconceivable to me that an ethical relation to land can exist without love, respect, and admiration for land, and a high regard for its value. By value, I of course mean something far broader than mere economic value; I mean value in the philosophical sense” (Leopold 1949, 223).

In the 1940s, ecologist and forester Aldo Leopold (1887-1948) worked on a book that continues to stir millions of readers to this very day: *A Sand County Almanac*, published posthumously in 1949. The almanac contains a collection of essays in which the author sets forth his views on “the delights and dilemmas of one who cannot […] live without wild things” (Idem, vii). Leopold concludes his almanac with a plea for a ‘land ethic’, an admonition to enlarge “the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land” (Idem, 204).

This study concentrates on one of the core messages of Leopold’s ‘land ethic’: every field of science, and especially biology, contains particular conceptions of nature. These conceptions are not merely epistemological or ontological; they have normative dimensions as well. They provide an *ethos*, a framework for moral orientation. These normative dimensions, whilst often remaining hidden and inarticulate,
influence the way in which biologists conduct their research and practice their profession. On certain occasions, however, normative aspects may suddenly rise to the surface, notably when moral clashes occur and biologists are confronted with conflicting images of nature (cf. Merchant 1989, 4). As environmental philosopher Martin Drenthen argues:

“We are faced with a plethora of moral views of nature, all of which are deeply contingent. Our concepts and images of nature are the result of processes of interpretation, in which all sorts of cultural and historical influences play a part. […] It is only when our basic beliefs about nature are challenged by ‘moral strangers’ that we become aware of the particularity or perhaps even idiosyncrasy of our views” (Drenthen 2005, 318).

I will explore the normative dimensions of biology by means of a case study from the Dutch ecogenomics field. Ecogenomics – short for ‘ecological genomics’ – is an area of research which seeks to incorporate techniques and approaches originating from genomics in an ecological context. As ecological research and laboratory-based molecular investigations traditionally occupied different areas within the biological sciences, this merging of ecology and genomics promises to “revolutionize our understanding of a broad range of biological phenomena” (Ungerer et al. 2008, 178).

During a memorable research meeting in February 2008, aimed at discussing the current state of Dutch ecogenomics research, a clash between ‘moral strangers’ took place. The participants in the meeting constituted a mixed audience: ecologists who took a more or less holistic

32 In the work of Richard Rogers, we can find a similar argument: “Our theories do matter to the extent that they are […] produced in a particular historical context, existing in a web of ideological affiliations, and potentially effective in the social and natural worlds. We must therefore take them seriously – not simply as more babel from the ivory tower, nor as ends in themselves, but as part of the ongoing construction of how the world, human beings, and social activity can and should operate” (Rogers 1998, 269).
to a reservoir to be exploited using the latest technologies (Ouborg, interview, September 2012).

In his work as a conservationist, Leopold noticed a ‘chasm’ similar to the one just described. In his view, the divide between different conceptions of nature was common to many specialised fields, such as forestry, agriculture, and wildlife management. In all these divides, Leopold argued, we can recognise the same basic ‘paradoxes’:

“[M]an the conqueror versus man the biotic citizen; science the sharpener of his sword versus science the searchlight on his universe; land the slave and servant versus land the collective organism” (Idem, 223 – author’s emphasis).

I will use Leopold’s ‘paradoxes’ as a starting point to explore the different conceptions of nature within the Dutch ecogenomics community. I will start by giving an overview of the developments that preceded the aforementioned ecogenomics research meeting. Next, I will analyse why ‘nature mining’ turned out to be such an explosive and provocative term. Finally, I will argue that, although at present the bulk of Dutch ecogenomics research reflects a more or less instrumental attitude towards nature, the field – in particular the metagenomic approach – also harbours other interpretations of nature as a significant and meaningful order, which could support a more humble and respectful approach to natural systems. A genomic approach to ecology might, for instance, cultivate the image of land as a ‘collective organism’, as proposed by Leopold.

33 Leopold’s use of the term ‘paradox’ appears to be somewhat misleading, as the views he describes seem to refer to ‘normal’ (i.e. non-paradoxical) oppositions.

34 In concert with my interviewees, I have decided to mention the researchers and institutes involved by name. This not only makes my analysis verifiable, but also enhances the tangibility and liveliness of the discussion.


36 At the end of section 3.10, I have inserted a figure presenting the research parties involved in the Dutch ecogenomics community.

37 Other key participants were Nico van Straalen, professor of animal ecology at VU University Amsterdam; Hans Westerhoff, professor of microbial physiology, also at VU; Hans van Veen, head of the department of microbial ecology at the Netherlands Institute of Ecology; Jan Kammenga, assistant professor at the laboratory of nematology of Wageningen University.

The ambition of Gnettic was

“to develop a set of genomics-based tools […] that can be used to analyze ecological systems, identify possible threats of contamination to the environment and human health, and to guide industrial production processes towards sustainable development” (Idem, 3).

The rationale for developing such a toolbox was that at the time, the level of understanding of ecological systems was inadequate for accurate predictions of responses to anthropogenic – i.e. man-made – disturbance. The biological instruments used in ecological assessments (biosensors, bioreporter systems, bioassays) were, in general, very labour-intensive. Moreover, they could only measure a limited number of targets at a given moment. The applicants argued that, in order to develop effective strategies for the sustainable production of animal and plant resources, major innovations were necessary. Genomics-based technologies enabled such innovations, “as they have the advantage that a multitude of targets can be evaluated at the same time with great responsiveness” (Idem, 3).

In analysing and managing ecological systems, Gnettic intended to apply two central approaches: metagenomics and the organism-centred approach. The first approach “enables us to study microorganisms in the complex communities where they actually live bypassing the need to isolate and culture individual community members” (Brouwer 2008, 1). In the 1990s, most microbiologists still assumed that the majority of microorganisms in a sample could be recovered by culturing them in the laboratory. An increasing amount of evidence nevertheless shows that “fewer than 0.1% of the microorganisms in soil are readily cultured using current techniques. […] the other 99.9% of soil microflora is emerging as a world of stunning, novel genetic diversity” (Handelsman et al. 1998, 245). By enabling the culture-independent genomic analysis of microbial populations, metagenomics “offers a window on an enormous and previously unknown world of microorganisms” (Handelsman 2007, 8).

The organism-centred approach (cf. Marco 2010, preface) seeks to improve our understanding of critical ecological interactions by focussing on the level of the individual organism. At the time of the Gnettic application, this approach was organised around classical laboratory-based model organisms, i.e. organisms with well-characterised gene expression patterns and large research networks around them, for instance the plant Arabidopsis thaliana and the nematode Caenorhabditis elegans (Maher 2009, 695; Ankeny & Leonelli 2011, 316). By exposing the model to different environmental conditions (humidity, drought, etc.), the genes and gene functions that matter most in a given ecological interaction were identified (Ungerer et al. 2008). Because of the homology among organisms, the insights obtained from classical model organism studies were expected to provide insight into the biology of ecologically interesting species as well: “We will exploit homologies across species to apply the insights obtained from models to other species, which are relevant for a wider range of environments than can be covered with the models only” (Brouwer et al. 2002, 5).

The grant application of Gnettic was accepted by NGI and resulted in the establishment of the Ecogenomics Consortium (EC) in 2003. Brouwer was appointed as its director. The NGI-funded programme was entitled “Assessing the living soil: An ecogenomics approach to explore and unlock sustainable life-support functions of soils.” The consortium was to receive substantial funding, amounting to 1.8 million euros a year for the period of 2004-2009. Brouwer and his partners believed that the goals of EC would be best met by substantial investments in basic academic research: “as they have the advantage that a multitude of targets can be evaluated at the same time with great responsiveness” (Idem, 3).

In analysing and managing ecological systems, Gnettic intended to apply two central approaches: metagenomics and the organism-centred approach. The first approach “enables us to study microorganisms in the complex communities where they actually live bypassing the need to isolate and culture individual community members” (Brouwer 2008, 1). In the 1990s, most microbiologists still assumed that the majority of microorganisms in a sample could be recovered by culturing them in the laboratory. An increasing amount of evidence nevertheless shows that “fewer than 0.1% of the microorganisms in soil are readily cultured using current techniques. […] the other 99.9% of soil microflora is emerging as a world of stunning, novel genetic diversity” (Handelsman et al. 1998, 245). By enabling the culture-independent genomic analysis of microbial populations, metagenomics “offers a window on an enormous and previously unknown world of microorganisms” (Handelsman 2007, 8).
research agenda. However, most did not complain as the EC funding was an additional opportunity to link their R&D activities to basic academic research” (Kloet et al. 2013, 212).

3.3 From publication to product

In January 2008, NGI announced that its director Diederik Zijderveld was leaving. His departure implied a significant change for EC. Under the supervision of the academically oriented Zijderveld, NGI had focussed on “creating a solid research infrastructure and a close-knit genomics community on the basis of excellent research” (NGI Annual Report 2008, 5). His successor Colja Laane, who had a background in industry, put a much stronger emphasis on ‘valorisation’, i.e. the process by which scientific knowledge is made profitable for society:

“Our emphasis will be: from Publication to Product […]. All money and effort put into research must result in more applications. Valorisation is the motto, in terms of patents, licenses and new businesses.”

NGI’s shift in emphasis put the consortium’s members in a difficult position. The mid-term review of EC, which took place during the second half of 2006, had already pointed out that “achieving interdisciplinarity and […] realizing the societal mission” (Kloet et al. 2013, 213) were weaker points of the programme needing attention. The review committee had argued that, whereas the consortium’s achievements in terms of scientific excellence were quite impressive, it had difficulties employing “the knowledge to effect positive changes for society” (Veldhuis & Peels 2007, cited in Kloet et al. 2013, 214). In order to be considered for the second round of funding, EC had to implement NGI’s valorisation demands. This led to the establishment of the Ecogenomics Innovation Center (ECOLINC), in which the ‘science-based’ focus of the 2004-2009 period was replaced by a more practical focus with a strong emphasis on “innovative aspects and valorization opportunities” (Brouwer 2008, 2). As Brouwer put it, “results and developments from the ongoing EC project have stimulated our ambition and increased our confidence that it is possible to assess and exploit nature’s vast hidden potential to develop sustainable applications in bio-based economy” (Idem, 1). ECOLINC received a follow-up grant of 3MEUR for 2009-2013 (compared to a budget of 11MEUR for 2004-2009).

The new focus of ECOLINC was clearly reflected in three of its main themes of investigation and valorisation. Firstly, the new programme sought to develop metagenomics and other ‘-omics’-based tools. The second theme dealt with the discovery of new functional capabilities of (un)cultivable microorganisms. Citing Brouwer again, “unleashing these hidden treasures will create a huge potential for applications in the fields of sustainable chemistry, alternative energy, in biorefineries, and in bio-construction materials” (Brouwer 2008, 2). Thirdly, ECOLINC focussed on the development of “novel genomics-based cellular and whole organism test systems as alternatives for non-animal tests” (Idem, 2). Such alternative test systems were necessary in chemical industry for the safety assessment of large numbers of existing chemical compounds.

3.4 The start of a new platform

The consortium’s move from basic ecogenomics research to a more practical approach was not unanimously welcomed. Whereas the industrial partners were happy with the “new market opportunities”, some of the academic partners “fundamentally disagreed with a focus on economic valorization” (Kloet et al. 2013, 213-214). To secure the “further

41 During the 2004-2009 period, EC generated 510 scientific publications (Kloet et al. 2013, 214).
3.5 Joining forces: the establishment of NERO

The establishment of PEEG did not put an end to the tensions within the Dutch ecogenomics community. To prevent the community from falling apart, the members of PEEG and ECO-LINC decided to set up an umbrella organisation, by means of which the two programmes could be presented as ‘intertwined’, albeit with different orientations:

“While both proposals have strong connections, they differ in the emphasis: NP-PEEG places emphasis on extending fundamental ecogenomics knowledge, as a requirement for developing applications, while ECO-LINC places emphasis on the development of ecogenomics knowledge for biotechnology, while exploiting existing fundamental knowledge” (Ouborg et al. 2009, 3).42

The umbrella organisation was called the Netherlands Ecogenomics Research Organisation (NERO). Its founding was not only considered a strategic move to calm things down, but also an effort to remain attractive for the financing parties. For indeed, to ensure continued funding the Dutch ecogenomics community needed to come across as a robust and solid party (Ouborg, interview, August 2013). NERO described its mission as follows:

“NERO will provide a platform function for ecogenomics, will act as co-ordinating organization, facilitating communication between the research field, financing agencies and end-users, will facilitate knowledge transfer in the form of workshops, thematic presentation days, and advanced international courses” (Ouborg & Kammenga 2008, 27).

3.6 Nature mining

Even though NERO presented PEEG and ECO-LINC as “two intertwined research programs” (Ouborg et al. 2009, 3), the friction between the two institutes became painfully clear during the very first National Ecogenomics Day (February 2008), the inaugural event in a series of annual meetings aimed at exploring the future of Dutch ecogenomics research. Moreover, it was on this occasion that NERO was to be officially introduced to the academic community at large. Position papers by leading experts

42 In his pre-proposal of ECO-LINC, Brouwer also refers to the connection between the two ecogenomics programmes: “… a fundamental ecogenomics research program will be added to the ECO-LINC proposal, funded by a separate source, namely the Earth & Life Science Program of the Netherlands Science Foundation” (Brouwer 2008, 2).
from the Dutch ecogenomics community were presented, stressing the importance and the relevance of ecogenomics for various sub-disciplines of biology. Brouwer was one of the speakers. Faithful to the new strategy of NGI, he argued that Dutch ecogenomicists should put more emphasis on the ‘valorisation opportunities’ of their field of research. He suggested that one way in which ecogenomics research could be translated into viable opportunities, was by means of ‘nature mining’ (cf. Brouwer 2008). With this term, he referred to one of the two basic experimental approaches within the metagenomics field: the function-driven approach, in which microbial DNA is screened for potential applications in medicine, agriculture, and industry (Handelsman 2007).43 Natural ecosystems contain a huge number of valuable assets, such as antibiotics, vitamins, and enzymes. Function-based metagenomics enables us to ‘mine’ environmental samples – soil, sediment, groundwater – for these hidden goods (cf. Brouwer 2008).

Brouwer’s use of the term ‘nature-mining’ instantly revealed the existing discord within the Dutch ecogenomics community. Part of the audience – especially those with a background in industry – immediately embraced the term. They expressed their enthusiasm by persuading the organising committee to give Brouwer the opportunity to finish his talk (he had to cut short his speech due to a lack of time) at the end of the meeting. Others – notably the ecologists associated with PEEG – were very reluctant. In spite of their efforts to emphasise the importance of “extending fundamental ecogenomics knowledge” (Ouborg et al. 2009, 3), Brouwer now suggested ECOLINC’s strategy as a model for all Dutch ecogenomics research. Some of the attendants even had the impression that Brouwer wanted the term ‘nature mining’ as the new ‘brand name’ for research in the field of ecological genomics.

However, the tensions between the various research parties involved in NERO do not only give evidence of a strategic conflict concerning the (future) direction of Dutch ecogenomics research; they also show a more fundamental difference between NERO’s rank and file. NERO had united researchers coming from different branches of the biological sciences: ecologists with a “comprehensive way of looking at the earth’s fabric of life” (Worster 1994, x), molecular biologists with a more “mechanical picture of nature” (Idem, 40), industrial biotechnology experts interested in new research equipment for exploiting microbial systems, as well as representatives of various intermediate positions. All these parties brought along their own normative perspectives, their particular ways of interpreting the natural world as a morally significant order. This normativity usually remains hidden, but as a result of Brouwer’s presentation, and more specifically his use of the term ‘nature mining’, it suddenly came to the surface.

In the introduction, I explained that Leopold wrote about a ‘chasm’ between different images of nature as early as in the 1940s. He observed a divide which he considered to be common to many specialised fields, such as forestry, agriculture, and wildlife management. Each of these fields can be divided into a group that “regards the land as soil, and its function as commodity-production,” and a group that “regards the land as a biota, and its function as something broader” (Leopold 1949, 221). In all these divides, Leopold recognised the same basic ‘paradoxes’:

“[M]an the conqueror versus man the biotic citizen; science the sharpener of his sword versus science the searchlight on his universe; land the slave and servant versus land the collective organism” (Idem, 223 – author’s emphasis).

In the following sections, I will use Leopold’s ‘paradoxes’ as a guideline for exploring the different existing conceptions of nature within the Dutch ecogenomics community.
3.7 Industrial mining

At the beginning of this paper, I explained that for some members of the Dutch ecogenomics community, the term ‘nature mining’ invoked an image of nature as a reservoir to be exploited using the latest technologies. As Joop Ouborg, co-founder of PEEG, put it: the term as such conveys a technocratic and human-centred image of nature. It echoes the question: how can we exploit nature to meet human needs? (Ouborg, interview, September 2012). In the field of environmental ethics, the interpretation of nature as a mere means to human ends is said to reveal an instrumental approach to nature (e.g. Rolston 1981; Curry 2006). Such an approach is based on the assumption that nature cannot have value independently of human needs and desires; it is thought to possess “meaning and value only when it is made to serve the human […] as a means to his or her ends” (Plumwood 2002, 109).

Why is the term ‘nature mining’ so strongly associated with an instrumental approach to nature? Obviously, this association largely revolves around the use of the term ‘mining’, i.e. the industrial process of extracting valuable minerals or other geological materials from the Earth. Mining is one of the most pronounced examples of a process in which nature appears as a resource, as a slave and servant (cf. Leopold 1949, 223). By polluting “the ‘purest streams’ of the earth’s womb”, mining operations “have altered the earth from a bountiful mother to a passive receptor of human rape” (Merchant 1989, 38-39). In order to mine, trees and vegetation often have to be cleared. Moreover, large scale mining operations depend on industrial-sized machinery to extract the metals and minerals from the soil. Severely polluting chemicals, such as cyanide and mercury, are required to extract these valuable materials. Large amounts of waste materials are often discharged into rivers, streams, and oceans.44

The image of nature as a slave and servant became dominant during the Scientific Revolution and the rise of a market-oriented culture in early modern Europe. In her famous book The Death of Nature (1989), philosopher and historian of science Carolyn Merchant argues that in the Renaissance era, a different image of nature was still prevalent. Inspired by ancient Greek philosophers such as Anaxagoras (500-428 B.C) and Theophrastus (370-278 B.C.), the Earth was viewed as a living organism and nurturing mother. This image had functioned as a normative constraint against the mining of Mother Earth: “One does not readily slay a mother, dig into her entrails for gold or mutilate her body” (Merchant 1989, 3). During the Scientific Revolution, this vitalistic image was replaced by a mechanistic view of nature: the Earth was no longer seen as a bountiful mother, but as an inanimate physical system. Merchant explains that the conception of the Earth as “a passive receptor” came to imply an approval of its exploitation, especially under the influence of Francis Bacon (1561-1626). She describes Bacon’s line of thought as follows:

“Due to the Fall from the Garden of Eden […], the human race lost its ‘dominion over creation’. […] Only by ‘digging further and further into the mine of natural knowledge’ could mankind recover that lost dominion. In this way, ‘the narrow limits of man’s dominion over the universe’ could be stretched ‘to their promised bounds’” (Idem, 170).

Merchant thus claims that in Bacon’s view, God had not forbidden the ‘inquisition of nature’. Enslaving nature was, on the contrary, according to His plan: ‘Nature must be ‘bound into service’ and made a ‘slave’, put ‘in constraint’ and ‘molded’ by the mechanical arts. The ‘searchers and spies of nature’ are to discover her plots and secrets” (Idem, 169). Merchant explains that for Bacon, miners and smiths were the models for a new class of explorers, as

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Earlier, I explained that the term ‘nature mining’ was only rejected by part of Brouwer’s audience. NERO’s industrial partners, notably, received this term with warm enthusiasm. One possible explanation for this might be that they overlooked what this particular vocabulary meant for nature; the latter was merely seen “as the ‘environment’ or invisible background condition […] against which the ‘foreground’ achievements of reason or culture […] take place” (Plumwood 1993, 4). Thus, in interpreting the term ‘nature mining’, the non-academic partners might have zoomed in on its positive impact on human progress, rather than on its destructive effects on nature. After all, the products of the mining industry have been, and still are, essential to human development.

Another explanation might be that the industrial partners – including Brouwer himself – had a different, more innocent and ‘neutral’ association in mind, namely ‘data mining’.

Since the beginning of the digital information era, data overload has become a very common problem; we simply gather more data than we can process. The field “concerned with the development of methods and techniques for making sense of data” (Fayyad et al. 1996, 37) is known as ‘knowledge discovery in databases’ (KDD). Data mining officially refers to one of the steps in the knowledge discovery process, namely “the application of specific algorithms for extracting patterns from data” (Idem, 39). However, today the term is frequently used as a synonym for KDD, thus defined as “the nontrivial extraction of implicit, previously unknown, and potentially useful information from data” (Frawley et al. 1992, 58).

What is the image of nature that comes to mind when we interpret ‘nature mining’ as a derivative of ‘data mining’, i.e. as the extraction of previously unknown, and potentially useful, information from large soil data sets? Contrary to industrial mining, data mining is a non-invasive approach: rather than extracting valuable ‘hardware’ (gold, coal, ore, etc.) we simply make sense of implicit information embedded in data. Yet, our understanding of ‘nature mining’ cannot easily be disconnected from its association with disruptive mining practices. Yet, this association was amplified with other, similar elements in the vocabulary used by Brouwer. As mentioned before, he refers to the soil as a treasure at human disposal:

“... the ‘Biotechnology for Nature’ field,” as if it goes without saying that nature itself will benefit from our biotechnological interventions. Thus it was the “particular combination of terms, as well as the distinctive ways in which these terms [were] interpreted and related to each other” (Van Wensveen 1999, 11), that underlined the provocative and controversial view of nature in Brouwer’s speech.

Van Straalen explained that, because of the resistance evoked by the term ‘nature mining’, EC’s leadership team sometimes preferred to use the term ‘unlock’, e.g. in the title of the NGI-funded ecogenomics programme: “Assessing the living soil: An ecogenomics approach to explore and unlock sustainable life-support functions of soils” (Interview, September 2013).
How has the Dutch ecogenomics field developed since the memorable research meeting in February 2008? As we have seen, NERO has had trouble keeping the different fractions of the Dutch ecogenomics community together from the very start. In June 2014, NERO will organise the 6th National Ecogenomics Day with funding from NWO. Apart from this annual meeting, not much has been heard from NERO in recent years (Hans van Veen, e-mail correspondence, September 2013).

Compared to the situation in 2008, ECOINC and PEEG have drifted even further apart. ECOINC has put the valorisation issue even higher on its agenda. In 2010, it became part of the BE-Basic Foundation (Bio-based Ecologically Balanced Sustainable Industrial Chemistry), "an international public-private partnership that develops industrial bio-based solutions to build a sustainable society." Brouwer is a key member of its leadership team, together with chemical engineer Luuk van der Wielen. Earlier, I pointed out that NGI had reserved a follow-up grant of 3MEUR for ECOINC. As part of the BE-Basic programme, ECOINC succeeded in obtaining an additional grant of no less than 18MEUR from the Economic Structure Enhancing Fund (FES), a policy-driven research fund. Officially, the BE-Basic programme would come to an end in 2015, but because of its success, it will continue until mid-2017.

The research conducted by BE-Basic is organised in ten 'Flagships', each addressing a significant scientific or socio-economic challenge. The seventh Flagship, entitled "High-throughput experimentation and (meta)genomic mining", seeks to develop and apply "high-throughput approaches and tools to explore and mine the metagenome." The vocabulary of the BE-Basic team reminds us of Brouwer’s speech during the first National Ecogenomics Day: nature appears as a resource for exploitation without constraint (cf. Plumwood 2002, 100). The term ‘nature mining’ has been replaced by ‘DNA-mining’, referring to the “search for enzyme variants in the total DNA pool found in [… ] soil and water samples.” Moreover, the study of nature is described in terms of hunting.

### 3.9 After 2008

How has the Dutch ecogenomics field developed since the memorable research meeting in February 2008? As we have seen, NERO has had trouble keeping the different fractions of the Dutch ecogenomics
3.10 Hopes for the future

The ways in which the research programmes of ECOLINC and PEEG have developed up till now remind us of one of the ‘paradoxes’ mentioned by Leopold. In the BE-Basic programme, science appears as the sharper of the researcher’s sword (cf. Leopold 1949, 223), or, to stick to the vocabulary of the leadership team, as a hunter’s weapon. It is interesting to see that this specific vocabulary is embedded in a programme that seeks to contribute to the development of “new sustainable production processes”54. Apparently, this instrumental language can be part of the rhetoric of sustainability. The two ESF-funded programmes – especially ConGenOmics – are based on a different vocabulary. As they seek to improve our overall understanding of critical ecological interactions, science does not appear as a ‘weapon’, but rather as a ‘searchlight’ for spotting complex ecological processes (cf. Leopold 1949, 223).

Moreover, instead of understanding natural ecosystems as mere “commodity-production” (Idem, 221), ConGenOmics explicitly seeks to protect natural ecosystems and its inhabitants from destructive human interventions.

In my view, there are various opportunities to include this more modest way of speaking into the BE-Basic programme, as well. Earlier, I explained that, in order to implement NGI’s valorisation demands, Brouwer and his research team increasingly concentrated on the development of metagenomics and other ‘-omics’-based tools. Compared to the organism-centred approach, this approach offers more opportunities for developing useful applications and products (e.g. medicines, vitamins, enzymes). At the present time, the usefulness of metagenomics to solve various complex human problems seems to encourage an instrumental approach to nature. However, this does not necessarily need to be so: the field also harbours other interpretations of nature as a significant and

53 Idem
54 Luuk van der Wielen. 6 December 2012. "BBE Beyond Bioethanol", Presentation as part of the ESF Research Conference Towards a Sustainable Bio-Based Society, Amsterdam.
meaningful order, which could form the basis for a more humble and respectful approach to natural systems. For example, metagenomics might cultivate the image of land as a ‘collective organism’, as has been proposed by Leopold; it shows us the interdependence of all life forms, or, to speak with Leopold, it shows us that we are all “member[s] of a biotic team” (Leopold 1949, 205). Traditionally, life is considered “to be organized around the pivotal unit of the individual organism” (O’Malley & Dupré 2010, 189). Metagenomics invites us to replace this ‘monogenomic’ conception by an organism- and species-free context: by demonstrating how genes “influence each other’s activities in serving collective functions” (Committee on Metagenomics 2007, 13), the field encourages us to “explain and predict [...] the behavior of the biosphere as though it were a single superorganism” (Idem, 139 – my emphasis). Thus, for some practitioners, the field moves us “inexorably in the direction of a Gaia-like concept of the world” (Dupré 2007, 200 – my emphasis; cf. Committee on Metagenomics 2007, 139).55

Another way in which metagenomics might endorse a more respectful approach to natural systems is by confronting us with the essential role of microbes in fulfilling all kinds of highly important human needs. Microbial communities – notably those residing in the soil – play a crucial role in the health and productivity of crops and in cleaning up contaminated environments. Moreover, they are essential for purifying drinking water and the development of new medicines (cf. Handelsman 2007; Committee on Metagenomics 2007). From this angle, metagenomics could even encourage us to embrace a conception of nature that connects with the mythical image of the Earth as a nurturing mother (cf. Merchant 1989); the field reminds us of the fact that we humans “are not only cultural beings but also natural beings, just as dependent on a healthy biosphere as other forms of life” (Plumwood 2002, 99). Therefore, one might say, even the field’s huge potential for products and applications does not necessarily need to go hand in hand with instrumental approaches to nature, but might, on the contrary, function as a basis for respect. But all this is no more than hope for the future. As Rogers argues: “The reconstruction of a different relationship to the environment in which we live requires radically alternative conceptions of humans, nature, material conditions, and discourse” (Rogers 1998, 268).

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55 This Gaian perspective is not only applicable to natural ecosystems, but also to our human bodies. Metagenomics has demonstrated that our bodies consist for 90 per cent of microbial, rather than ‘human’ cells. As a result, metagenomics encourages us to conceive ourselves as collective organisms or ‘supraorganisms’ as well (Turnbaugh & Gordon 2008; O’Malley & Dupré 2007; Drenthen et al. 2009).
References


NGI Annual Report. 2002. “There still is a great deal of pioneering to be done, interview with Prof. dr Bram Brouwer”. Nederlandse Organisatie voor Wetenschappelijk Onderzoek.


Chapter 4
Hunting for nature’s treasures or learning from nature? The narrative ambivalence of the ecotechnological turn
Words are like empty balloons, inviting us to fill them up with associations. As they fill they begin to gain intrinsic force and at last to shape our perceptions and expectations.

– Donald Worster, 1994

4.1 Introduction

Over the past few decades, biological knowledge has grown rapidly. We have discovered that the mechanisms and processes of nature are much more complex, intricate and interwoven than we ever imagined. As “[w]e can see, more clearly than ever before, how nature works her miracles” (Benyus 2002, 6), an increasing number of scientists, designers, and engineers claim that we are entering a new technological era, in which we are ‘re-inventing’ our relationship with nature (cf. Ball 2001; McDonough & Braungart 2002; Benyus 2002). Whereas more traditional technological approaches are based on principles that are different from, and often disturb or interfere with the dynamics of nature (Sloterdijk & Heinrichs 2006), new technological approaches are increasingly inspired by “nature’s surprisingly effective design principles” (McDonough & Braungart 2002, 6). This desire to produce technological devices that mimic the natural world as closely as possible reveals an ‘ecotechnological turn’, meaning that nature’s own strategies, developed in the course of the long and winding road of evolution, provide the models for our innovations.

Scientists have found various ways to express this shift towards more ‘natural’ approaches to nature, making use of different narrative structures, metaphors, and images. With these ‘narrative self-presentations’, they seek to express in what ways the new approach to technology can be distinguished from the old, as well as to legitimise their research activities.
narrative comes with a promise as well, albeit a rather different one: if we listen carefully to nature’s lessons, pay close attention to the ways in which our teacher tackles design challenges, we will ourselves become smarter and better problem solvers as well. Here, the ‘prize’ is not so much a material, but rather an intellectual reward.

Yet, as we will argue in this paper, both the treasure quest and the teacher-student narratives are much more ambivalent and multidimensional than the scientists using those narratives seem to realise. They are embedded in larger, more common narratives which can be found throughout our culture, for instance in literature, art, and film. We will show how these genres reveal the ambivalence and complexity of both narratives, using two well-known movies as illustrations. As an example of an archetypical moral narrative about treasure hunting, we will concentrate on Steven Spielberg’s first Indiana Jones movie *Raiders of the Lost Ark* (1981). Subsequently, to illustrate what is at stake in the teacher-student narrative, we will focus on the theme of the sorcerer’s apprentice, which achieved global popular fame through Walt Disney’s 20th century animated cartoon version entitled *The Sorcerer’s Apprentice* (1940).

4.2 Metagenomics as a practice of treasure hunting

A typical example of an emerging field of research that endorses an ecotechnological perspective, is metagenomics, i.e. “the culture-independent genomic analysis of microbial communities” (Schloss & Handelsman 2003, 303). In the 1990s, most microbiologists still assumed that the majority of microorganisms in a sample could be recovered by culturing them in the laboratory. An increasing amount of evidence has nevertheless shown that “fewer than 0.1% of the microorganisms in soil are readily cultured using current techniques. […] the other 99.9% of soil microflora is emerging as a world of stunning, novel genetic diversity” (Handelsman *et al.* 1998, 245). By enabling the culture-independent
Metagenomics claims that the discovery of new genes and functions in soil "is one of the potential treasure troves of metagenomics" (Handelsman 2007, 8). Knowledge of this world can help us solve various complex human problems:

"Metagenomics [...] promises to provide a more complete understanding of the global cycles that keep the biosphere in balance, offer clues to the basis for many diseases, lead to development of new antimicrobial therapies and present solutions to environmental and biotechnological challenges" (Idem, 8).

Secondly, metagenomics allows the study of microbial communities under nature’s own conditions. Researchers in this field are aware of the fact that the artificial environments created in labs are very different from natural environments. In order to obtain a critical and realistic understanding of microbes in nature, they consider it essential to investigate microbial populations in their native habitats. Metagenomics can therefore be said to announce a new era in biology, “that of ecosystems biology” (Xu 2010, 1).

To draw attention to the wealth of products and applications yet to be discovered with the help of metagenomics, in various scientific publications and programmatic documents, this new practice of uncovering the Earth’s microbial diversity is compared to a quest for a treasure (e.g. Oh et al. 2003, 248; Park & Kim 2008, 163; Schoenfeld et al. 2010, 20;). For instance, Brouwer argues that “unleashing these hidden treasures will create a huge potential for applications in the fields of sustainable chemistry, alternative energy, in biorefineries, and in bioconstruction materials” (Brouwer 2008, 2). Moreover, the Committee on Metagenomics claims that the discovery of new genes and functions in soil "is one of the potential treasure troves of metagenomics" (2007, 76).

By presenting metagenomics as a quest for the valuable ‘goods’ still hidden in nature, researchers in this field not only seek to make understandable, but also to legitimise their research activities. This particular self-presentation gives the field an aura of adventure: it brings to mind the age of the great explorations. That metagenomics can also be an adventure in a literal sense is best illustrated by the global ocean sampling expeditions carried out by scientists at the J. Craig Venter Institute. For more than a decade, these scientists "have been on a quest to unlock the secrets of the oceans by sampling, sequencing and analyzing the DNA of the microorganisms living in these waters."

Most importantly, however, the treasure quest narrative reflects an investment that will require full commitment, yet with the promise of great reward in the end. This reward should primarily be understood in material terms; the narrative self-presentation especially refers to products to be developed based on the as-yet-undiscovered goods that lie hidden in the soil (or other natural ecosystems), such as enzymes and antibiotics (Handelsman 2007, 6). The confidence that the metagenomic quest is an effort worth making, is also expressed by the amount of money invested in metagenomic research. Research projects at the J. Craig Venter Institute, for instance, are funded not only by government institutions (such as NSF and NIH), but receive great sums of money from family foundations as well. Thus, the prospect of new products beneficial to humans plays an important role in the justification of metagenomics, and is instrumental in helping to raise the required funding for what is yet a very open endeavour with a very uncertain outcome; metagenomics

Apart from describing metagenomics as a practice of treasure hunting, some scientists refer to this research field as revealing “the earth’s bounty” (cf. Rondon et al. 1999, 403; Sleator et al. 2008, 361). Moreover, the metagenomic process of uncovering the Earth’s microbial diversity has also been referred to as ‘nature mining’ (cf. Brouwer 2008).

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Idem
is one of the ‘-omics’ research fields that “give rise to quite substantial promises and expectations for society”, a ‘promisory’ practice which has been referred to as promisomics (Chadwick & Zwart 2013, 1).

4.3 Resourcism

In the context of metagenomics, the ecotechnological turn is presented as a quest for the ‘goods’ that nature has produced in the process of evolution. Nature appears as a super-innovator whose creations we can incorporate into our own technologies. There are, however, also more critical voices, claiming that the treasure quest narrative does not give a full picture of what is at stake in ecotechnology. Although this narrative underlines the superiority of nature’s innovations, nature is still presented as a ‘resource’. Resourcism has been the object of fundamental criticism by environmental thinkers for a long time. Neil Evernden describes resourcism as “a kind of modern religion which casts all of creation into categories of utility” (1993, 23). It is based on the conviction “that nature is for something” (Idem, 10) and should therefore be protected.62 Resourcism was in itself a justified reaction against earlier forms of environmental advocacy, “preoccupied with aesthetics and metaphysics” (Idem, 4). It sought to replace the impractical and emotional testimonies of nature lovers like Henry David Thoreau and John Muir by rational arguments, underlining that wise management of natural resources is necessary to maintain current standards of living. Thus, “[w]here once only an anguished cry could be expected in defence of a threatened mountain or an endangered species, now a detailed inventory and a benefit-cost analysis [were] sure to be forthcoming” (Idem, 9).

According to Evernden, one of the typical features of resourcism is the strict separation between human and non-human nature. This feature is strongly represented by the American conservationist Gifford Pinchot (1865-1946), who believed that there were “just two things on this material earth – people and natural resources” (1947, 325). Evernden explains that this belief implies “the total dedication of the planet to human purposes – or rather to the contemporary human economy” (1993, 150). Another result of separating the world in merely two realms – i.e. a human and a non-human realm – is that the complexity of the latter is severely underestimated. As Evernden argues: nature is treated “as homogeneous matter in search of a use” (Idem, 23). Val Plumwood, in a similar vein, claims that this homogenisation makes us insensitive to nature’s marvellous diversity. The variety of nature is only taken into consideration if it is expected to contribute to human prosperity: “Nature is conceived in terms of interchangeable and replaceable units, (as ‘resources’, or standing reserve) rather than as infinitely diverse and always in excess of knowledge and classification” (2002, 107).

However, according to Evernden, resourcism entails an even more dangerous aspect, namely “its apparent good intention. By describing something as a resource we seem to have cause to protect it. But all we really have is a license to exploit it” (1993, 23 – our emphasis). The transformation of “all relationships to nature into a simple subject-object or user-used one” (Idem, 24) goes hand in hand with the devaluation of nature. Reducing a tree to a device that produces oxygen, argues Evernden, is debasing to being itself. In a similar fashion, describing microbial ecosystems as treasure troves reduces the world of microorganisms to “another material thing that can be utilized by humans” (Idem, 24).

4.4 Biomimicry as a tutorial practice

The resource approach to nature is not only criticised by environmental thinkers, but increasingly also by scientists. In an attempt to give a less instrumental, less reductionist account of the stakes of ecotechnology,
some of them have proposed another narrative; one that does more justice to nature’s own creative processes. The American science writer and innovation consultant Janine Benyus argues that we should “view nature as a source of ideas instead of goods”\(^63\). In her influential book *Biomimicry: Innovation Inspired by Nature* (2002), Benyus describes how her outlook on nature management went through a change. During her forestry studies, a reductionist, human-centred approach to nature management prevailed:

> “In reductionist fashion, we studied each piece of the forest separately […] There were no labs in listening to the land or in emulating the ways in which natural communities grew and prospered. We practiced a human-centered approach to management, assuming that nature’s way of managing had nothing of value to teach us” (2002, 3).

When Benyus started writing books on wildlife habitats, she was surprised by “the exquisite ways that organisms are adapted to their places and to each other” (Idem, 4). She began to wonder why human beings, while facing the same physical challenges as all other living beings, sought to meet those challenges through human cleverness alone. It was then that Benyus decided to develop an alternative approach, in which organisms and natural systems are no longer regarded as resources available for unrestricted use, but as “the ultimate teachers” (Idem, 4 – our emphasis). Benyus gave this approach the label ‘biomimicry’, derived from the Ancient Greek βιος, meaning *life*, and μιμησις, meaning *to imitate*. She describes biomimics as “men and women who are exploring nature’s masterpieces […] and then copying these designs and manufacturing processes to solve our own problems” (Idem, 2).

What is so revolutionary about this “conscious emulation of life’s genius” (Idem, 2)? After all, there is a long history of engineers and scientists who gained inspiration from nature (cf. Ball 2001, 413). A classic example are the Wright brothers, who succeeded in flying the first heavier-than-air airplane in 1903, taking inspiration from observations of turkey vultures in flight. In the 1950s, the American engineer Otto Schmitt turned this nature-inspired approach into a more or less formal discipline. Instead of biomimicry, Schmitt used the term ‘biomimetics’ to describe the “transfer of ideas and analogues from biology to technology” (Vincent et al. 2006, 471). Benyus, however, appears to be (one of) the first to explicitly connect this discipline with “a new way of viewing and valuing nature” (2002, front pages). She explains that biomimicry is much more than a particular approach to solving engineering problems:

> “In a society accustomed to dominating or ‘improving’ nature, this respectful imitation is a radically new approach, a revolution really. Unlike the Industrial Revolution, the Biomimicry Revolution introduces an era based not on what we can extract from nature, but on what we can learn from her” (Idem, 2).

What does Benyus seek to express with her presentation of biomimicry as a tutorial practice? By introducing this alternative narrative, she distances herself from interpretations of the ecotechnological turn that – implicitly – support the conviction that “the world was put here exclusively for our use” (Idem, 8). To enable more respectful approaches to nature, it is not enough to recognise the excellent quality of the ‘goods’ produced by nature, nor will it suffice to see nature as a superior innovator; it requires that we start looking differently at ourselves as well. The recognition of nature as our mentor implies that we simultaneously recognise ourselves as nature’s students, open to the lessons that nature has in store for us:

> “Once we see nature as a mentor, our relationship with the living world changes. Gratitude tempers greed, and, […] “the notion of resources becomes obscene.” We realize that the only way to keep learning from nature is to safeguard naturalness, the wellspring of good ideas” (Idem, 9).
What kind of promise is contained in the presentation of biomimicry as a teacher-student relationship? How can this particular self-presentation legitimise the research activities of biomimics? Whereas the treasure quest narrative spoke of a material reward in the form of new products beneficial to humans, in the context of the teacher-student narrative the ‘prize’ is, above all, of an intellectual nature: if we listen carefully to nature’s lessons, pay close attention to the ways in which our teacher tackles design challenges, we will ourselves become smarter and better at solving problems as well. Benyus explains that nature has 3.8 billion years of design brilliance available for free: “After 3.8 billion years of research and development, failures are fossils, and what surrounds us is the secret to survival” (Idem, 3). Benyus’s message did not fall on deaf ears: since the foundation of the Biomimicry Guild in 1998, she has inspired thousands of scientists, architects, designers, and innovators to use nature’s models to create sustainable technologies, or, to put it differently, to become biomimics themselves.

4.5 Stories small and large

Benyus presents the tutorial narrative of biomimicry as being radically different from the treasure quest narrative of metagenomics. Nevertheless, these two narrative self-presentations are also strikingly alike in one respect: adherents of both sides have chosen these narratives because they are believed to provide unproblematic models with positive connotations only. By connecting their research activities to these ‘positive’ stories, metagenomicists and biomimics seek to legitimise their work. However, the two narrative self-presentations are embedded in larger, more common cultural narratives, to which they implicitly refer and which lend them their motivational force. This especially applies to the treasure quest narrative: by mentioning the word ‘treasure’, the audience immediately thinks of adventure and feels the excitement of discovery. However, even though ecotechnologists may more or less consciously refer to more general narrative structures, they seem to be insufficiently aware of the fact that the broader treasure quest and teacher-student narratives are quite ambivalent and multidimensional. What is more, some of these broader stories are explicitly moral: they show us what is at stake in the practical situations we humans can find ourselves in.

When ecotechnologists ignore the inherent ambivalence of these broader moral narratives, they may find that their narrative self-presentations evoke unintended responses among audiences; the ambivalence that is repressed in a superficial and straightforward use of the narrative will re-emerge in the way in which the message is perceived and appreciated by others. What is intended to be an unambiguous story about our effort to do something univocally ‘good’ can unwillingly evoke moral sentiments of a much more complicated nature. In the next sections, we will show the ambivalence of both the treasure quest and teacher-student narratives by using well-known movies as an illustration.

As an example of an archetypical moral narrative about treasure hunting, we will look at Steven Spielberg’s first Indiana Jones movie *Raiders of the Lost Ark* (1981). To illustrate what is at stake in the teacher-student narrative, we will focus on the theme of the sorcerer’s apprentice, a story that is based on Goethe’s classic poem *Der Zauberlehrling* (1797), but achieved global popular fame through Walt Disney’s 20th century animated cartoon version entitled *The Sorcerer’s Apprentice* (1940).

4.6 Raiders of the Lost Ark

Treasure hunting is a classical theme in literature, art, film, etc. As explained in the above section, most stories dealing with this theme are surprisingly multi-layered and ambivalent. Typically, they show sympathy for those who yield to the temptations of treasure hunting, but also contain a lesson about the risks of giving in to this temptation. In many treasure quest stories, we meet two types of hunters: one most of us sympathise...
with – a character who seeks the treasure mainly to satisfy his (or her) intellectual curiosity, but nevertheless shows not to be immune for its material value; and another who seeks the treasure for his profit alone, whose greed has turned him into a villain. Usually, the latter comes to a bad end in the dramatic closing scene, whereas the former has gained a new perspective on the trivial meaning of the search for personal gain.

One of the best-known contemporary treasure hunter tales is that of Indiana Jones. In our paper, we will concentrate on the first part of the Jones series: Raiders of the Lost Ark (1981). The film, directed by Steven Spielberg and produced by George Lucas, tells the story of the archaeologist Indiana ‘Indy’ Jones. Indy, played by Harrison Ford, is hired by the American government to prevent the Nazis from getting hold of the Ark of the Covenant, which is believed to still hold the Ten Commandments. The anti-Semitic Nazis seek to turn this Jewish artefact into a weapon of world conquest and domination.

In the opening scenes, Indy is portrayed as an adventurous treasure hunter. As spectators, we get the impression that he is one of the raiders referred to in the title of the film. We see images of the thick jungle on the South American continent. The year is 1936. Indy narrowly escapes death in an ancient temple, in which he is searching for a golden idol. Finally standing face to face with the incredibly well-protected statuette, he does not hesitate to remove it from its resting place. We are nevertheless sympathetic to Indy. Why do we consider him a hero, in spite of the fact that some of his actions are morally dubious? The main reason appears to be that Indy does not fit to the picture of an ordinary plunderer, who is blinded by greed. More than a raider, Indy is an archaeologist who seeks to fulfill his intellectual curiosity. He is searching for rare and ancient artefacts because of their cultural and historical significance. Moreover, Indy does not keep the treasures for himself: they will be stored in a museum, accessible to the public.

We find out more about the ‘academic’ side of Indy in the second scene, where Indy, wearing glasses and a suit, teaches archeology to a class of mainly female students, who clearly adore him. At the end of his lecture, Indy is interrupted by the curator of the National Museum of Washington, and two US Army intelligence agents, who appoint him with the mission to find the Ark of the Covenant before the Nazis do. The spectator discovers that Indy’s search for the Ark is not only curiosity-driven, but also ethically motivated: Indy wants to prevent the Nazis from becoming unconquerable. The Ark is believed to hold immense mystical power:

“The Bible tells of it leveling mountains and wasting entire regions. Moses promised that when the Ark was with you, your enemies will be scattered and your foes fell before you. […] An army which carries the Ark before it is invincible” (Raiders of the Lost Ark).

Indy’s heroism becomes even more pronounced in contrast with his French nemesis René Belloq. Despite being an archeologist like Indy, Belloq is driven by the quest for personal glory and power only. His immorality is underlined by his willingness to collaborate with the Nazis. Throughout the film, Belloq is trying to convince Indy that the two of them are one of a kind. Belloq’s first attempt occurs when he meets a depressed and drunken Indy. The latter assumes that his (former) lover Marion has died in an explosion. It is then that Belloq tells him:

“You and I are very much alike. Archaeology is our religion, yet we have both fallen from the purer faith. Out methods have not differed as much as you pretend. I am a shadowy reflection of you. It would take only a nudge to make you like me, to push you out of the light” (Raiders of the Lost Ark).

Examples of other movies in this genre are Treasure Island (e.g. 1950 and 1990), based on the novel by Robert Louis Stevenson (1883); King Solomon’s Mines (e.g. 1937 and 1950), based on the novel by Henry Rider Haggard (1885); Mutiny on the Bounty (e.g. 1935 and 1962); The Mummy (1999, 2001, and 2008); National Treasure (2004 and 2007); The Librarian (2004, 2006, and 2008).
As spectators, we can see the doubt in Indy’s eyes: he almost seems to believe that Belloq is right. Not only Indy, but also the spectator is invited to ponder the extent to which Belloq’s reflections are correct. Indy is very eager to find the Ark before Belloq and the Nazis do, not only to prevent them from increasing their power, but also to keep up his reputation; the quest for the Ark is also a competition between two prominent archaeologists, having their own professional pride, and defending their countries’ honour.

Indy’s persistence is confirmed by the fact that he does not heed the warnings of his wise friend Sallah. When the two friends discuss the Well of Souls, the secret chamber in which the Ark is buried, Sallah’s face gets a worried expression. After some hesitation, he tells Indy: “Indy, there is something that troubles me. […] The Ark. If it is there, at Tanis, then it is something that man was not meant to disturb. Death has always surrounded it. It is not of this earth” (Raiders of the Lost Ark).

The film does not show Indy’s response to Sallah’s worries, but the spectator becomes aware that the stakes are high: if Indy fails to respond appropriately, things will go seriously wrong. Indy is warned again when his digging party finds the actual location of the Well of Souls. The opening of the chamber is joined by the sound of thunder and lightning. When Indy looks inside, he does not only see a stone altar, but also a thick grey moving carpet.

“It’s alive. It’s thousands and thousands of deadly poisonous snakes – Egyptian asps. And the only thing that seems capable of avoiding this venomous groundcover is the altar. The snakes ebb and flow near it, but never encroach on it, as though repelled by some invisible force” (Kasdan & Lucas 1979, 64).

Although frightened, Indy is not taken aback by the mysterious forces that seem to be at work here: he fends off the snakes and seizes the Ark. But he is not able to keep it in his possession for long: Belloq and the Nazis take it from him, leaving Indy inside the well, together with Marion.

The question concerning the likeness between Belloq and Indy keeps coming back almost until the end of the movie. Belloq, who has again ‘stolen’ the Ark from Indy, tells the Nazis that he wants to test its power before presenting it to Hitler (whereas in fact, he wants to keep the Ark for himself). When they arrive on a desert island, Indy reveals himself and threatens to destroy the Ark with a bazooka. Belloq, however, realises that Indy wants to know what the Ark contains as much as anyone:

“Yes, blow it up! Blow it back to God. All your life has been spent in pursuit of archaeological relics. Inside the Ark are treasures beyond your wildest aspirations. You want to see it open as well as I. Indiana, we are simply passing through history. This… this is history. Do as you will” (Raiders of the Lost Ark).

While Belloq performs a ceremonial opening of the Ark, Indy and Marion are fastened to a post. At first, the Ark appears to contain nothing but sand dust, the remains of the stone tablets. Suddenly, however, spirits emerge from the Ark. It is at this exact moment that the crucial difference between Belloq and Indy becomes clear: aware of the supernatural danger of looking at the unveiled Ark, Indy warns Marion to close her eyes: “Marion, don’t look at it. Shut your eyes, Marion. Don’t look at it, no matter what happens!” (Raiders of the Lost Ark). Meanwhile, the spirits change into angels of death; Belloq and all the Nazi soldiers die terrible deaths.

4.7 Contextualised criticism

The scene in which Indy warns Marion to close her eyes is the film’s pivotal moment. We have seen that Indy starts his quest for the Ark with noble intentions. But in the process of getting closer to it, he yields to the temptation of making it his own. Face to face with the Ark’s mystical powers, Indy realises – and we as his spectators with him – that power and greed almost blinded him: he now understands that not the Ark,
but the wisdom obtained during the expedition, is the most important prize. Belloq’s refusal to learn this lesson leads to his gruesome end. By featuring two types of treasure hunters, the narrative structure of the movie reminds the audience that treasure hunting has its moral challenges, and that we are at risk of losing our souls if we let ourselves be blinded by greed.

In the second Jones-film, *Indiana Jones and the Temple of Doom* (1984) – which, apart from the end, has a rather thin storyline – this moral message is expressed even more clearly. The inhabitants of a small Indian village ask Indy to retrieve a sacred rock that has been stolen from them by the followers of an evil cult. Having survived an incredible number of deadly traps, Indy hands over the rock to the village leader. Night-club singer Willie, who earlier in the film was shown to have a weakness for diamonds, notes that he could have kept the rock, on which Indy answers her: “What for? They’d just put it in the museum, it’d be another rock collecting dust.” Willie counters him by saying: “But then it would have given you your fortune and glory.” However, Indy realises that the value of his quest lies in the lessons learned, not in possessing the sacred rock. He tells the village leader that he “understand[s] its power now” (*Indiana Jones and the Temple of Doom*).

What lessons could metagenomic researchers learn from *Raiders of the Lost Ark*? What is the film’s surplus value compared to the criticism on resourcism expressed by Evernden and Plumwood? *Raiders reveals* a strikingly subtle stance towards treasure hunting. The main reason for this appears to be that the criticism is an inherent dimension within the story: it is not an external comment or afterthought, but a dimension that unfolds as the story progresses. By introducing Indy and Belloq as two opposites (who nonetheless seem to show at least some resemblances), the film pictures treasure hunting as a practice that is not by definition ‘good’ or ‘bad’. *Raiders* is sympathetic to the temptations of treasure hunting, yet at the same time confronts us with one of its inherent dangers, namely that the promise of possessing the ‘prize’ may become an obsession, obscuring any insight. It shows us that, in the process of getting closer to the treasure, we run the risk of losing our soul. By contrast, the philosopher’s criticism on resourcism remains to a large extent external. If we express Evernden’s and Plumwood’s criticism in terms of treasure hunting, they seem to focus on one form of treasure hunting only, namely the greedy, Belloqian variant. As the criticism expressed in *Raiders of the Lost Ark* is much more subtle, it seems more capable of showing metagenomic researchers what is at stake: we ourselves are at stake if we become obsessed by the material reward awaiting us.

By looking at the broader cultural narrative of treasure hunting, we learn that moral knowledge about the risks inherent to this practice is at least implicitly present in the popular cultural domain. Of course we could have referred to more ‘highbrow’ forms of art and literature. But what the Indiana Jones example shows us, is that even a Hollywood blockbuster narrative on treasure hunting is much more ambivalent than the univocal self-presenting narrative of metagenomicists. It should therefore not come as a surprise that their self-presentation is not univocally applauded but rather meets with skepticism and moral reservation. It is not enough to know that the metagenomic quest for the goods of nature contains the promise of a treasure; we also need to be assured that this quest is not blinded by greed. For as ‘we’ all know, not much good can come from that.

### 4.8 The Sorcerer’s Apprentice

What about the alternative narrative of ecotechnology? As we showed earlier, Benyus seeks to provide a different perspective on the implications of the ecotechnological turn. It is not enough to recognise the superiority of nature’s goods; we have to become nature’s humble students, showing respect for nature’s superior wisdom (cf. Benyus 2002, 9). But here, again, the self-presentation relies on a larger, more widely shared moral narrative about what it means to be a pupil, and about what can go wrong.

A classical story that resonates in Benyus’s presentation of
dreams that he is a powerful sorcerer standing on a mountaintop, from where he commands the stars and the sea.

Suddenly, Mickey wakes up to find the room awash with water: the cauldron is overflowing, as the broom keeps carrying water to it. Being unable to stop the broom, Mickey grabs an axe and chops it into pieces. Just when things seem to have calmed down, Mickey’s attempt to break the spell turns against him: each of the pieces transforms into a whole new broom. Soon, a whole army of brooms is fetching water to the cauldron. Mickey turns over the leaves of his master’s book, hoping to find the right formula to stop the brooms. Just as Mickey is about to drown, a stern and angry Yen Sid appears. With a wave of his hands, the waters recede. Mickey, looking very guilty, takes off the sorcerer’s hat and returns it to its rightful owner. Then he picks up the buckets and continues with his chores.

4.9 Hubris

The tale of The Sorcerer’s Apprentice confronts us in a lighthearted manner with the dangers of overestimating oneself. Mickey Mouse’s hubris seems to be twofold. Firstly, he is not aware of his incompetence and assumes that he already fully understands and controls his master’s powers. Having been successful in enchanting the broom, this assumption is initially confirmed. Only after things have gone wrong, he realises that he is not yet ready to imitate Yen Sid. But there is also a more fundamental hubris at work in Mickey’s attempt to use his master’s magic for his own purposes. Mickey seems to be unaware of the difference between tricks and magic; he mistakenly assumes that magic is only about tricks. Mickey does not understand that there are things that cannot be learned by reading textbooks or diligent practice. This second form of hubris brings to light an (other) important difference between Mickey and his master. Yen Sid is not only smart, but also wise: he knows how to separate essentials from trivialities. Mickey, on the contrary, does not (yet) fully

biomimicry as a tutorial practice is The Sorcerer’s Apprentice. Reflecting on this story can help us to understand what is at stake in biomimicry. The tale of The Sorcerer’s Apprentice knows many versions. Its original goes back almost 2000 years, and is attributed to the rhetorician and satirist Lucian of Samosata (2nd century AD). Probably today’s most well-known version of the story is Walt Disney’s ten-minute animated version of The Sorcerer’s Apprentice, which is the third segment of the film Fantasia (1940). This particular version is based on Paul Dukas’s symphonic interpretation L’apprenti sorcier (1897) of Goethe’s poem Der Zauberlehrling (1797). The popularity of the Disney version is shown by the fact that in Fantasia 2000, the sequel to the 1940 film, the segment about the apprentice Mickey Mouse is the only one retained. Following the story from Goethe’s poem closely, Disney introduced the tale to a worldwide audience. The dialogue-free cartoon is introduced by a narrator, who gives a characterisation of the apprentice, a role played by Mickey Mouse:

“He was a bright young lad; very anxious to learn the business. As a matter of fact, he was a little bit too bright, because he started practicing some of the boss’s best magic tricks before learning how to control them” (Fantasia).

The cartoon starts with images of the powerful sorcerer Yen Sid (Disney in reverse), who is practicing his magic. His apprentice Mickey is fetching water to fill a cauldron. After a long yawn, Yen Sid puts his hat down and retires to his chambers. Mickey is visibly happy with the opportunity to take his master’s place: tired of carrying the buckets, he puts Yen Sid’s hat on and tries to enchant a broom to do the work for him. The spell works, which seems to encourage Mickey in thinking that he is his master’s equal. He sits down in Yen Sid’s chair and falls asleep. He

65 In describing the learning process that turned her into a real biomimic, Benyus compares herself to the Sorcerer’s Apprentice: “… but like the Sorcerer’s apprentice, I managed only to create more duckweed” (2002, 286).
recognise the insignificance of some of his objectives. Unable to see the bigger picture, he uses his master’s magic powers for something as trivial as fetching water. If Mickey would have used the sorcerer’s powers for more serious purposes, the latter probably would not have gotten angry. Yen Sid seems especially annoyed by the fact that Mickey’s decision to use his master’s spells is motivated by laziness, and does not serve any serious goal.66

What could Benyus and other biomimics learn from the tale of The Sorcerer’s Apprentice? The tale shows us that the knowledge acquired during our teacher’s lessons can bring us into trouble, especially if we do not realise that our knowledge is only fragmentary and finite. Even in the process of getting smarter and smarter, we have to remember that we are still students, and, in a certain manner, will always remain so. Moreover, the tale encourages biomimics to reflect on the question whether they keep their eyes on the bigger picture, for instance when they compare nature to “a superior R&D department.”67 We just argued that Mickey, capable of performing (at least some) spells, still needs to learn to choose his goals carefully. Or, to cite another Hollywood hero, Mickey has not yet fully grasped that “with great power comes great responsibility” (Spider-Man). In a similar vein, it is important that biomimics continue to look critically at the objectives to which they apply nature’s lessons. They have to keep asking the question: “Why do we want what we want?” Comparing nature to a research and development department involves a projection of what we consider to be important. The realisation that nature is much more than a ‘problem solving machine’ could help distinguish between serious demands for new technologies and the more trivial motives that

66 Unlike Yen Sid, Goethe’s sorcerer is not angry with his apprentice for having tried to equal his master. He tells off the broom for having followed the orders of someone other than his old master: “Back now, broom./Into the closet! /Be thou as thou/wert before! /Until I, the real master/call thee forth to serve once more!” (translated by Brigitte Dubiel).

67 Bas Sanders. 31 October 2013. “Biomimicry – Leren van de natuur?” Presentation as part of the symposium “Het wezen van duurzaam”, Hortus Arcadië, Radboud Universiteit Nijmegen. Benyus also describes nature in terms of R&D: “After 3.8 billion years of research and development, failures are fossils, and what surrounds us is the secret to survival” (2002, 3).

are also at play in current technology development.

The above shows that, although Benyus opposes the tutorial narrative to presentations in which nature appears as a source of ‘goods’, her narrative self-presentation has its own ambiguity. In the end, the ‘bad’ student who uses his teacher’s lessons merely to empower himself is not that different from the greedy treasure hunter who seeks the treasure for his own profit alone. Thus, the proposal to view nature as a source of ‘ideas’ rather than ‘goods’ does not protect Benyus from the dangers inherent to the latter narrative self-presentation: not only nature’s goods, but also her wisdom can be used in a reductionist and instrumental fashion.

4.10 Conclusion

Science needs narrative structures, metaphors, and images to explain and legitimise research practices that are usually described in an abstract and technical manner in academic publications and programmatic documents. Yet, in their narrative self-presentations, scientists tend to underestimate the complexity and multi-layered character of these narratives, notably in terms of the moral message they convey. This also applies to the two narratives of ecotechnology that were analysed in this paper. Ecotechnologists seem to use them to emphasise the positive potential for society and nature of the research field in question. Yet, as we have shown, even popular cinematic versions of these narratives reveal the moral ambivalences they entail. And this applies both to the treasure hunting and to the tutorial narrative. This means that genres of the imagination (novels, fairytales, poems, but also movies) can be used as a window into the ambivalences and ambiguities of the narratives employed. Rather than refraining from using narrative self-presentations, we argue that, whenever scientists use them, this richness must be more explicitly addressed.
References

Chapter 5
The homeotechnological turn: Sloterdijk’s response to the ecological crisis
5.1 Introduction

Since the late 20th century human beings have become increasingly aware of the vulnerability of planet Earth. Reports such as The Limits to Growth (Meadows et al. 1972) have confronted us with the boundaries of nature’s tolerance. Moreover, we have discovered that the mechanisms and processes of nature are much more complex, intricate and interwoven than we ever imagined. According to various contemporary environmental thinkers, these insights into the vulnerabilities and dynamics of nature have transformed the character of modern technologies; increasingly, our technologies become biomimetic, i.e. similar to nature. Since biomimetic technologies pretend to act and think in accordance with nature’s own principles of operation, they are expected to bring about a more sustainable and peaceful co-existence of humans and nature than more traditional technological approaches (Benyus 2002; McDonough & Braungart 2002).

In this paper, I will analyse the writings of one particular author who tries to take the idea of biomimetic technologies seriously, namely the German philosopher Peter Sloterdijk (1947). Instead of biomimicry, he prefers to use the term homeotechnology (derived from the Ancient Greek ὁμόιος, meaning ‘alike’ or ‘similar’). Sloterdijk presents his work on the ‘homeotechnological turn’ as a Heideggerian “critical theory of being-in-the-world” (Sloterdijk 1989, 13). Yet he explores this “in-der-Welt-sein”
from a new dimension. In a special issue of Society and Space on The worlds of Peter Sloterdijk, Elden and Mendieta argue that “Sloterdijk […] is engaged in a Heideggerian project concerning the nature of being, but not in relation to time […], but in relation to space” (Elden & Mendieta 2009, 8 – my italics). Hence, Sloterdijk invites us to regard his magnum opus, the Spheres Trilogy (1998; 1999; 2004, published together 2005),70 as the sequel (Being and Space) to Heidegger’s Being and Time (Sloterdijk 1998, 345). In his Spherology, Sloterdijk attempts to rewrite the history of western metaphysics by understanding human beings as inextricably – almost symbiotically – connected with the artificial ‘interiors’ or ‘envelopes’ in which they exist. From the beginning of human history, Sloterdijk argues, we have been building artificial ‘spheres’ in order to immunise – i.e. protect – ourselves against the threatening outside world. These self-created spaces not only exist as material environments (houses, villages, cities, states), but also as symbolic immune systems (religions, metaphysical systems, or ideologies such as humanism). With these “self-spun illusory bubbles” (Sloterdijk 1998, 23), we aim to transform reality into a secure and habitable dwelling place.

In Foams, the final part of his Spherology, Sloterdijk argues that, as a consequence of scientific and technological developments, our symbolic bubbles have burst. Since we killed God with the dissecting knives of science, the “monosphere” of metaphysics has lost its immunological function. We are left with the fragments of the comprehensive spheres in which human beings used to feel secure. To restore our feelings of security, we have replaced our symbolic immune systems by technological immunisations. In this way, we regained a certain amount of control over our environment. Although this transition towards technological forms of immunisation started with the 17th century scientific revolution, in Sloterdijk’s view, the 21st century has laid the foundation of a new chapter in the history of immunisation. Due to the looming threats of a worldwide environmental catastrophe, the global environment of planet Earth has turned into one big ‘interior space’ [Innenraum]. As each of our individual actions might affect the global ecology, “the practice of externalisation is faced with an absolute boundary” (Sloterdijk 2009a, 712). We are forced to consider the ecological dimension of our being-in-the-world. Sloterdijk believes that the rise of homeotechnology should be thought of as an attempt to immunise ourselves against the threats of a worldwide cataclysm. Contrary to classic ‘alototechnology’, in which humans are opposed to nature, homeotechnology presupposes a conception of humans as ecological beings. In his contribution to the special issue of Society and Space, Van Tuinen puts the human–nature relationship underlying homeotechnology as follows: “nature or physis itself appears as the integral production process in which we are embedded and with which we cooperate” (Van Tuinen 2009, 109).

Although I appreciate the evocative and inspiring manner in which Sloterdijk fleshes out the ‘rescue potential’ of homeotechnology, I will argue that his reflections are based on a series of problematic assumptions. For example, he not only claims that homeotechnology is “founded on an imitatio naturae” (Sloterdijk & Heinrichs 2006, 329), but also assumes that the ability to incorporate nature’s basic operating principles – such as replication, selection, and transgenesis – in our own technologies is inextricably bound up with a co-operative, domination-free approach to nature. As I will argue, the conviction that we (already) understand nature’s principles of operation sufficiently to imitate them appears to be fairly hubristic. Moreover, it presupposes that nature reveals itself in a particular way, namely as an assembly line of biomolecular processes. Even if we assume that at some point we will succeed in imitating nature’s most complex and refined processes, this does not as a matter of course preclude domination. Rather, “doing it nature’s way” (Benyus 2002, 2) opens up new prospects for exploitation, for instance in the case of genetic manipulation. What is more, since current technoscience obscures the classical distinction between ‘biomachines’ and ‘manmade machines’, this exploitation runs the risk of becoming increasingly subtle and invisible. Thus, homeotechnology may result in strengthening our sway over nature even on a molecular level.

70 Blasen (Bubbles), 1998; Globen (Globes), 1999; Schäume (Foams), 2004; published together as Sphären (Spheres), 2005.
The structure of this paper is as follows. In the first section, I will discuss Sloterdijk’s core message as brought forward in his recent monograph *You Must Change Your Life* (2009a), in which he urges us to consider how each of our actions affects the global ecology. Next, I will show how he relates this message to the possibility of increasing the Earth’s carrying capacity by means of homeotechnology. After analysing the ways in which, in Sloterdijk’s view, homeotechnology distinguishes itself from traditional forms of technology, I will critically reflect on the ‘rescue potential’ of homeotechnology. In the final section, I will argue that the ‘homeotechnological turn’ can only be effected if it is developed within the context of an ecological ethos different to the technocentric ethos that currently dominates our attitude towards nature. Sloterdijk claims that homeotechnology is based on the recognition of the ecological dimension of our being-in-the-world. Nonetheless, he has not thoroughly considered the practical and moral implications of our ecological situatedness. An example of a philosopher who has more adequately reflected on the broader cultural framework within which (homeo)technology could be successfully implemented, is the Australian eco-feminist Val Plumwood (1938-2008). Building on her final work *Environmental Culture: the Ecological Crisis of Reason* (2002), I will present some preliminary thoughts on how we can develop “an integrated democratic science that is dialogical, non-reductionist and self-reflective” (Plumwood 2002, 53) as a necessary moral supplement to Sloterdijk’s homeotechnologies.

5.2 Change your life!

At the end of *You Must Change Your Life* (2009a), Sloterdijk claims that, since the prospect of a worldwide catastrophe has become a disquieting threat, we are confronted with a new imperative that addresses each of us personally: “Change your life! Otherwise its complete disclosure will demonstrate to you, sooner or later, what you failed to do during the time of portents!” (Sloterdijk 2009a, 702). How can we live up to this imperative? In answering this question, Sloterdijk builds on the writings of Hans Jonas. In *The Imperative of Responsibility* (1984), Jonas claims that, due to technological developments, the range and impact of human action has increased dramatically. In ancient times, ethics was concerned with the “intrahuman frame” (Jonas 1984, 4). It focussed on the duties of human beings towards their fellow human beings. Since we were incapable of inflicting permanent damage on nature on a sizeable scale, our obligations towards the natural realm remained outside the scope of ethics. Jonas further argues that traditional ethics was restricted to proximity, in terms of time as well as space: “Ethics [...] was of the here and now, of occasions as they arise between men, of the recurrent, typical situations of private and public life” (Idem, 5). In Jonas’s view, modern technology has changed this; it has added a whole new dimension to our sense of responsibility: “the nature of human action has *de facto* changed, and [...] an object of an entirely new order – no less than the whole biosphere of the planet – has been added to what we must be responsible for because of our power over it” (Idem, 7). According to Jonas, we are only capable of adequately evaluating the ethical significance of contemporary science and technology with the help of a new kind of ethics, that is anticipatory and forward-looking, an Ethics of Responsibility. Ethics must develop, assess and critically compare scenarios for the future. As part of this future-oriented ethics, Jonas developed a new imperative, sometimes referred to as the ecological imperative: “Act so that the effects of your action are compatible with the permanence of genuine human life” (Idem, 11).

Jonas’s line of thinking is taken up by Sloterdijk. He explains that the prospect of a worldwide, man-made cataclysm urges us to consider how each of our actions affects the global ecology. We have to be constantly aware that we are members of a *world-wide nation*. According to Sloterdijk, this is extremely difficult for us. Building on his *Spheres Trilogy*, he argues that, up till now, our systems of solidarity have been effective only on a smaller scale, for example within families,
or tribal, regional and national unities. Now, the scale of our responsibility is crossing all borders. As the terrestrial sphere has turned into one big ‘interior space’, Sloterdijk urges us to move away from a traditional dualistic scheme based on ‘self’ versus ‘other’, or ‘culture’ versus ‘nature’. We must move towards a mentality in which the ‘we’ and the ‘us’ are the prevailing categories of moral thinking. To put it differently: we must get rid of the distinction between environmental and other contexts. There is nothing beyond the environmental context (Mathews 2011):

“Since the ‘global society’ reaches its limits and the earth with its fragile atmospheric and biospheric systems has presented itself once and for all as the limited collective scene of human operations, the practice of externalisation is faced with an absolute boundary” (Sloterdijk 2009a, 712).

### 5.3 The carrying capacity of the Earth

During the 2009 United Nations Climate Change Conference in Copenhagen, Sloterdijk gave a lecture on the metaphor of ‘Spaceship Earth’ (Buckminster Fuller 1969), elaborating on his views in You Must Change Your Life. Until recently, Sloterdijk argued, human beings were allowed a large degree of ignorance as regards navigation and maintenance of their spaceship, as the system was designed to accommodate a high degree of human stupidity. But this has now changed. We sense that we have reached a limit and are using up our last resources. Due to this growing awareness, the admonition “Change your life” stands at the core of our ethical intuitions. It confronts us with a binding commitment to create a modus vivendi that corresponds with the ecological-cosmopolitan insights of our culture. How to develop such a responsible way of life? Sloterdijk argues that, at first sight, an ethics of global moderation – to which he also refers as ‘ecological Puritanism’ and ‘ecological Calvinism’ – appears to be the only sensible answer to the looming worldwide catastrophe. Such an ethics would imply the reversal of the direction in which civilisation has moved up to now:

“the ethics of the future […] calls for a decrease where the agenda to date has been to increase, it demands minimization where thus far all that counted was maximization, it urges restraint where until now explosion was in order, it decrees thriftiness where to date extravagance was felt to be the greatest excitement, it admonishes us to restrict ourselves where up till now self-liberation was celebrated” (Sloterdijk 2011, 103).

On second thoughts, however, an ethics of moderation must be regarded as illusory; it clashes with the forces driving advanced cultures such as ours. Building on the work of Nietzsche, Sloterdijk argues that the human condition is characterised by an inherent tendency towards luxury and extravagance. He describes the style in which modern humanity exists as ‘kinetic expressionism’, i.e. “the style of being-in-the-world […] enabled primarily by the easy availability of fossil fuels” (Idem, 97). This way of life “penetrates the entirety of our ‘metabolism with nature’, our production, our consumption, our living, our transport, our arts and communications” (Idem, 103). According to Sloterdijk, modern human beings will refuse to give up their kinetic lifestyle: “They will remain convinced that it is the task of evolution through constant growth to globalize material prosperity and the expressive privileges they themselves enjoy. They will refuse to come to terms with a future that is based on reduction and restraint” (Idem, 107).

If an ethics of global moderation on its own is unrealistic, how should we face the challenges ahead? The ecological Puritans claim

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72 A lecture entitled How big is “big”? (Wie groß ist “groß”?).

73 Cf. Nietzsche, Daybreak 405: “The tendency towards luxury is rooted in the depths of a man’s heart: it reveals that the superfluous and immoderate is the water wherein his soul prefers to float.”
that, in the long run, the affluent people of today have no other choice than to give in to the ecological facts. Sloterdijk, however, maintains that this conviction is based on a false assumption. The Puritans view the Earth and its biosphere as a single, non-multiplicable monad. They argue that, since we have only this one Earth at our disposal, “we must accept that the limits take precedence over the impulse to exceed them” (Idem, 107). Sloterdijk claims that, thanks to recent technological advances, this ‘monadological’ interpretation of the Earth might prove to be outmoded. In the course of social evolution, the biosphere has joined forces with “the technosphere, which is in turn animated and directed by a noosphere [i.e. the sphere of human cognition]” (Idem, 108 – my emphasis). Thanks to the possibility of a convergence of these three dimensions, the resilience of the Earth can be increased. As Sloterdijk puts it: “It is not excluded a priori that this could produce effects that would be equivalent to the Earth’s multiplication” (Idem, 108 – my emphasis). Sloterdijk explains that until now, we regarded technology from the angle of environmental damage and bionegativity. Technology, however, has not yet played its final card: “By re-aligning the technosphere to meet homeotechnological and biomimetic standards, in the course of time a completely different image of the interaction between the environment and technology will arise” (Idem, 109).

In order to grasp Sloterdijk’s view of the role of technology in increasing the Earth’s carrying capacity, we must see how the considerations discussed above build on his earlier work. In the next section, I will analyse how, in Sloterdijk’s opinion, the supportive potential of the planet could be amplified or even multiplied thanks to “a sort of turn [i.e. a Heideggerian ‘Kehre’] in the process of technology itself” (Sloterdijk & Heinrichs 2006, 329-330). My analysis will draw from his essay “Domestication of being” (2001) and the book Neither Sun nor Death (2006), in which Sloterdijk answers questions concerning technological catastrophes posed by the German writer Hans-Jürgen Heinrichs.

5.4 Human machines versus biomachines

According to Sloterdijk, the various contrivances and machines that human beings have developed throughout the ages are fundamentally different from the ‘biomachines’ – the living organisms – produced by nature. Whereas biomachines are the temporary result of complex processes of mutation, natural selection and other evolutionary mechanisms, the vast majority of human technologies developed up to now display a tendency to counteract or disturb the dynamics of nature:

“Nature knows of no pure rotations; it knows nothing that corresponds to the technical principle of the bow and arrow, and has seen barely anything that is equivalent to the prototechnics of tying and knots; in nature there exist no piston engines and certainly nothing of that which metallurgists do” (Sloterdijk & Heinrichs 2006, 328-329).

According to Sloterdijk, the anti-natural tendency of traditional human technologies resulted from our inability to imitate nature’s processes: “as engineer of life [nature] developed its own strategies of evolution, strategies that until now were too complex for us to mimic” (Idem, 328). Manmade machines tended to be characterised by radical simplifications. Thus, we produced a plethora of tools (from the wheel up to the combustion engine) that were nowhere to be found in nature. Sloterdijk understands these simplifications as practices of immunisation: they allowed us to stand up against uncertainties and granted us a certain amount of control over our environment.

Inspired by Gotthard Günther’s distinction between ‘classic’ and ‘trans-classic’ – i.e. cybernetic – technology (Günther 1963), Sloterdijk refers to traditional human technology as ‘allotechnology’. With the
concept of ‘allo’ – derived from the Ancient Greek ἄλλος, meaning ‘other’ or ‘alien’ – he indicates that the classic design of human technology is based on principles that are different from, and often disturb or interfere with, nature’s own dynamics and processes. Moreover, allotechnologies put to work “reductionist and authoritarian intentions” (Sloterdijk & Heinrichs 2006, 330). They display a “reckless exploitation of life chances […] as well as a senseless wasting of so-called resources” (Idem, 330). Sloterdijk understands the exploitative nature of allotechnology as a result of its dualistic conception of reality. Drawing on Günther’s work on philosophy and cybernetics, he argues that traditional western culture – i.e. classical metaphysics – has approached ‘being’ with a false dichotomy. Classical metaphysics has divided reality in two separate ontological domains: subject vs. object, spirit vs. matter, nature vs. culture, etc. According to Sloterdijk, this has led to “the absolute inability to describe in an ontologically adequate manner ‘cultural phenomena’ such as tools, signs, artworks, laws, customs, books, machines and all other artifices” (Sloterdijk 2001, 217). These phenomena are neither fully subjective, nor fully objective:

“All cultural objects are by their very constitution hybrids with a spiritual and a material ‘component’, and any effort to say what they ‘really’ are in the framework of a bivalent logic and a monovalent ontology, inevitably results in hopeless reductions and destructive shortenings” (Idem, 217).

Sloterdijk sees the metaphysical divide reflected in the allotechnological tendency to use natural materials and energy sources to ends that are indifferent or even alien to nature: “the division of being into subject and object [shows itself] in the difference between master and slave, as well as that between workman and raw material” (Idem, 224).

5.5 The image of nature

Yet, according to Sloterdijk, a ‘turn’, a new chapter in the history of technology seems to be emerging. The 21st century represents “a paradigm shift in the basic idea of technology” (Sloterdijk & Heinrichs 2006, 329). With the rise of modern technoscience – biotechnology, neuroscience, nanotechnology, cybernetics – the fundamental principles of traditional human technologies are under revision. Increasingly our technologies become biomimetic, i.e. similar to and compatible with nature. Notwithstanding the fact that all human operations are essentially technological, new technologies approach the natural world in a radically new and different way: they borrow from nature’s own pool of technologies and initiate applications that are strikingly similar to nature’s own processes, on a molecular and microscopic level. According to Sloterdijk, modern technoscience has dealt with the necessity to simplify the most minute and intricate mechanisms of nature: “It seems that we find ourselves, for the first time, on the threshold of a form of technology which will be sufficiently developed to pass itself off as a radical imitation of nature” (Idem, 329).

Whereas most contemporary thinkers use the term ‘biomimicry’ to refer to this new type of technology (e.g. Hawken, Lovins & Lovins 1999; Benyus 2002; Bensaude-Vincent et al. 2002; Mathews 2011), Sloterdijk introduces the term ‘homeotechnology’ – derived from the Ancient Greek ὁμοίος, meaning ‘alike’ or ‘similar’. He describes the revolutionary nature of homeotechnology with the aid of the following three concepts. Firstly, as mentioned above, homeotechnology aims at achieving an imitatio naturae. This “only became possible after far-reaching insight was attained into the modus operandi of the self-organisation of living matter” (Sloterdijk & Heinrichs 2006, 329). Secondly, Sloterdijk characterises homeotechnology as a “non-dominant [nicht-herrische] form of operativity” (Sloterdijk 2001, 227). Whereas allotechnology enslaved and exploited nature by neglecting nature’s own principles of operation, in the homeotechnological age, “the ‘materials’ are […] conceived in accordance with their own stubbornness, and are integrated
into operations with respect to their maximum aptitude” (Idem, 227). According to Sloterdijk, this shift from a dominating to a domination-free approach entails a rupture with the traditional metaphysical classification of being. In his view, we have to thank Günther for replacing the dualistic conception of reality with a bivalent ontology and a polyvalent logic. Günther developed this post-dualistic toolkit from his experiences in the field of cybernetics. In the 1940s and 1950s, this discipline began to demonstrate the technological modifiability of processes we used to classify as entirely subjective. From that time onwards, properties that were thought to belong exclusively to the human realm – e.g. intelligence – have been simulated by machines. Sloterdijk claims that, in our time, the most spectacular interference of the mechanical with the subject is brought about in the field of biotechnology. Gene technologies especially “draw a broad variety of physical preconditions of the Self into the range of artificial manipulations” (Idem, 221).

The third concept related to homeotechnology is co-operation. We can identify two different interpretations of this term in Sloterdijk’s writings. ‘Co-operation’ first of all refers to the incorporation of nature’s operating principles – replication, selection, transgenesis – into our own technologies. Here, the co-operative nature of homeotechnology should be interpreted in a technological or instrumental sense: modern technoscience connects with the principles of life itself. However, the kind of co-operation enabled by homeotechnology exceeds the sheer technological or instrumental level. We can also discern in Sloterdijk’s work what I would like to call a normative interpretation of this term, as denoting a co-operative attitude towards nature. Since homeotechnology acts and thinks in accordance with nature’s own operationality, its co-operative nature should be seen as opposed to the dominating stance of allotechnology. As Sloterdijk puts it in “Domestication of being”: homeotechnology relies on “co-intelligent, co-informative strategies. It is characterised by co-operation rather than domination” (Sloterdijk 2001, 228).

What is Sloterdijk’s motivation for using the term ‘homeotechnology’ instead of the more established ‘biomimicry’? First of all, whereas the latter term refers to a particular approach to solving engineering problems, the philosophical concept of homeotechnology seeks to describe how modern technology presents itself to us. Secondly, it is important to keep in mind that for Sloterdijk, homeotechnology belongs to a pair of concepts: it is the counterpart of allotechnology. As mentioned before, these twin concepts are inspired by Günther’s distinction between ‘classic’ and ‘trans-classic’ technology. A third motivation might relate to the difference between imitating and incorporating biological machinery. Sloterdijk considers biotechnology – i.e. the incorporation of biological systems in industrial and scientific processes – the ultimate example of homeotechnology. However, in biomimicry literature, biotechnological uses of nature are generally seen as running counter to the principles of biomimicry. For instance, the French philosopher of science Bernadette Bensaude-Vincent argues that “biomimicry […] aims to mimic life, not to reproduce it” (Bensaude-Vincent et al. 2002, 1; cf. Benyus 2002, 2).

Fourthly, homeotechnology refers to the imitation (or incorporation) of nature’s principles at a particular level. Whereas the term biomimicry covers the imitation of life on all possible scales – e.g. learning from humpback whales how to create efficient wind power, and from termites how to create sustainable buildings (cf. the Biomimicry Institute, Montana), homeotechnology refers to the imitation (or incorporation) of nature’s molecular and microscopic processes.

5.6 Responsible citizenship

Earlier I explained that according to Sloterdijk, the imperative “Change your life!” addresses each of us personally. Since the Earth has presented itself as the limited scene of human operations, we must all
join forces in order to prolong its fitness for human habitation. As we have seen, Sloterdijk doesn’t urge us to secure the planet’s condition – in order to safeguard human life on Earth – by means of an ethics of global, state-enforced moderation; as humanity is characterised by an inherent tendency towards luxury and extravagance, such an ethics would be illusory. In fact, the solution to the crisis Sloterdijk suggests in his Copenhagen lecture refers to a change of technology rather than a change of lifestyle: thanks to the emergence of homeotechnology, the resilience of the Earth can be increased.

The promise of modern technoscience to provide a fitting solution to the crisis appears to overshadow the importance of Sloterdijk’s call to change our lives. If homeotechnology is the answer to the worldwide catastrophe, to what extent are we still expected to work on ourselves as well? It is important to stress that, for Sloterdijk, the shift towards homeotechnology is not brought about by us as agents, but rather emerges as a ‘turn’, a moment of transformation in the history of technology as such. However, this does not mean we can afford to sit back. Sloterdijk urges us to be responsive to the way in which nature and technology manifest themselves as a consequence of this technological change. We can support and boost this change by displaying a readiness to shape our *modus vivendi* using an alternative technological framework. This is a typical Heideggerian element in Sloterdijk’s approach. The crisis calls for a responsive form of activity rather than an activist one. We have to open ourselves to the opportunities offered by technology itself. This is the moment we have been waiting for, the new tide. As Sloterdijk himself points out, the homeotechnological turn involves an ethos of confidence and preparedness that is almost Gospel-like in nature. Human beings are like the shepherds of Being awaiting the coming dawn:

“what on earth are the guardians of Being? […] This much is clear, namely, that Heidegger’s pastoral discourse is eminently ethical, insofar as it demands a particular form of restraint, of concentration, of modesty, of listening, of preparation […]. We are called upon to pay attention and to attend, like the five wise virgins of Matthew 25, who guarded their lamps until the bridegroom arrived. The readiness for the Call of Being is all” (Sloterdijk & Heinrichs 2006, 127).

In explaining how human beings can live responsibly, I have focussed on how Sloterdijk assesses the role of individual citizens. But what about policy and governance? For Sloterdijk, the attitude of the current political elite underlines the importance of citizens taking up their personal global responsibility. The 2009 UN summit in Copenhagen is only one example of a political event that proved a big disappointment. Instead of opening up a new era of responsibility, the conference ended in a frustrating stalemate and a diplomatic debacle. According to Sloterdijk, the Copenhagen Conference and other similar fiascos show that the political elite currently in power does not have the will to effect the necessary change through concerted action on a global level. Sloterdijk ascribes this to ‘national egoism’; most politicians are only interested in protecting their own national spheres. Hence, the technological transition must occur elsewhere, not in the context of political summits, but through a bottom-up combination of technological innovation (the emergence of homeotechnology) and responsible citizenship (adoption of homeotechnology in response to the looming cataclysm). In an interview at the UN summit, Sloterdijk elaborated on his lecture by explaining that the will to change must eventually become the will of the majority. Even if, in the beginning, Europe will be alone in adopting homeotechnology, in due course it will be implemented by all important partners on a truly global scale. Why is Sloterdijk so convinced of this? Because “we live in a world that is helpless against the better example” (Sloterdijk 2009b).

5.7 The rescue potential of homeotechnology

In the previous section I explained that, for Sloterdijk, the fact that modern technoscience takes the lead in tackling the environmental crisis does
largely unknown world of uncultivable microbes, the field offers great opportunities to revolutionise our understanding of planet Earth as a microbial planet (Handelsman 2007). Paradoxically, however, precisely by improving our knowledge of microbial life, metagenomics confronts us with the fact that for the greater part, the Earth is still a terra incognita. In fact, more than 99 per cent of soil microbes are still unknown to us (Handelsman et al. 1998; Riesenfeld et al. 2004). The metagenomics example shows that, even though modern technoscience proves how little we actually know of nature's complexity, many scientists still assume that eventually, its mechanisms and processes will not only be knowable, but also controllable and even (re)makeable. This idea, which is of course not restricted to metagenomics, has raised many critical responses. Eric Katz, for instance, expresses moral objections against the idea “that we can discover the plan, the methods, the processes of nature, and mold them to our purposes” (Katz 2000, 87):

“The human presumption that we are capable of this technological fix demonstrates (once again) the arrogance with which humanity surveys the natural world. Whatever the problem may be, there will be a technological, mechanical, or scientific solution. Human engineering will modify the secrets of natural processes and effect a satisfactory result” (Idem, 85-86).

Even if we imagine that at a certain point we will gain access to even nature’s most complex and refined mechanisms, we need to look critically at the process that precedes this imitation of nature. How do we obtain the knowledge required in order to copy nature? Taking metagenomics as our example again, it becomes apparent that microbial systems can only come to serve as models after being completely uprooted, after a kind of vivisection of these systems. More generally, it could be argued that we can only start to imitate nature after first unlocking nature’s secrets by means of technology. In other words, we can only imitate a nature that has been made technologically reproducible.
Homeotechnology: a co-operative, non-dominant technology?

When it comes to clarifying some of the ambiguities entailed by Sloterdijk’s concept of homeotechnology, the two possible meanings of the term co-operation become important. As already indicated, the term co-operation can be used first of all in a technological or instrumental sense, namely in the sense that we actually develop specific tools allowing us to interact with natural processes on a molecular scale. But the development of such tools is inspired by the idea of co-operation in a more normative sense: the idea that human beings should see themselves as partners or collaborators rather than as masters of nature. Sloterdijk himself doesn’t draw a clear distinction between these two meanings; he presents them as if they are two sides of the same coin, in other words, as if they presuppose each other. Why does Sloterdijk assume that our ability to incorporate nature’s principles in our own technologies is inextricably bound up with (and will more or less automatically lead to) an attitude towards nature that no longer strives for mastery and domination? Sloterdijk’s answer is basically that nature’s own feedback mechanisms will simply shut the door to authoritarian practices. Nature will only share her secrets of operation if we adjust our actions to her own processes: “Nature can only be imitated after the rupture with the technology of wastage, which is always also something of a technology of violation” (Sloterdijk & Heinrichs 2006, 330). Homeotechnology “can lead to successes to the extent that it proceeds in a fashion that is analogous to nature and without authoritarian encroachments” (Idem, 330). In “Domestication of Being”, Sloterdijk even goes so far as to connect homeotechnology with a new kind of ethics: “One may even ask whether or not homeotechnological thought [...] has the potential to unleash an ethics of relationships free of enmity and domination” (Sloterdijk 2001, 230-231). In other words, a domination-free ethos does not precede or inspire the development of homeotechnology, but is rather embedded and entailed in it. Homeotechnology as such already conveys a co-operative, non-dominant message.

Yet one could still argue that “doing it nature’s way” (Benyus 2002, 2) does not, as a matter of course, preclude domination. On the contrary, opening up the molecular pathways of nature might rather ‘fuel’ our will to power, our will to control and rule over living nature (cf. Lemmens 2008). Returning to the example of metagenomics, it becomes clear that, precisely by uncovering nature as a domain of complexity and sophistication, modern technoscience opens up new prospects for exploitation, for instance by means of genetic manipulation and ‘nature mining’ – exploring the soil to unearth its hidden treasures. Following Eugene Thacker, one could argue that, in the homeotechnological age, biological information – i.e. information about biochemical processes, protein folding, DNA-replication, etc. – has become the raw material; it plays the same role as coal, petroleum and ore did (and still do!) in the industrial age (Thacker 2005).

So, rather than unleashing a domination-free ethics, mere technological or instrumental forms of co-operation might pave the way for even more radical intrusions of humans into nature than those achieved by classic allotechnology. Whereas allotechnological interventions are in general rather flagrant and indelicate, and as such clearly visible to the eye, homeotechnology enables the domination of nature in more sophisticated, subtle and hence concealed ways. This invisibility is increased by the fact that homeotechnology obscures the traditional distinction between ‘biomachines’ and ‘manmade machines’. Citing Katz again, we could argue that homeotechnology is – or threatens to become – the “unrecognized manifestation of the insidious dream of the human domination of nature” (Katz 2000, 84).

Homeotechnology: opposed to allotechnology?

I have argued that we not only have to look critically at the extent to which homeotechnology is capable of imitating nature’s molecular and microscopic processes; we also need to question Sloterdijk’s claim that homeotechnology will – more or less in and of itself – lead to a co-operative, domination-free approach to nature. If homeotechnology

78 This statement strongly reminds us of Francis Bacon’s famous quote in Novum Organum (1620), that “Nature to be commanded must be obeyed.”
is not necessarily and by definition ‘good’ for nature, it seems appropriate to ask ourselves in what ways it actually distinguishes itself from allotechnology. Paraphrasing Janine Benyus, co-founder of the Biomimicry Guild (Montana): “What will make the Homeotechnology Revolution any different from the Industrial Revolution? Who’s to say we won’t simply steal nature’s thunder and use it in the ongoing campaign against life?” (Benyus 2002, 8).

On the technological level, the difference between allo- and homeotechnology is quite clear. Contrary to allotechnology, homeotechnology explicitly aims to copy or incorporate the ‘design principles’ of nature itself. On the normative level, however, the difference between allo- and homeotechnology is less obvious. If homeotechnology, in spite of its likeness to nature, is not by definition ‘good’ for nature, the question arises as to whether allotechnology is necessarily ‘bad’ for nature. From my point of view, allotechnology does not automatically estrange us from nature; it might also strengthen our relationship with our natural surroundings (cf. Kockelkoren 1994). This is illustrated by our first space travels. It was only after (allo)technology allowed us to see the Earth from the perspective of the moon-traveller that we were able to develop an Earth awareness (Lemmens 2011). By taking the ‘God’s eye view’, we became aware of the uniqueness of “this small blue ball in the vastness of black space” (Scott 2001, 411). We started to realise that if we do not take care of the Earth as such, we ignore the lives of its inhabitants. The author Norman Cousins clearly expresses how space travel laid the foundation of our ecological awareness: “What was most significant about the lunar voyage was not that men set foot on the moon but that they set eye on the earth” (cited in Scott 2001, 411). This is just one example of how even our most dominant and anti-natural forms of technology can deepen our relationship with nature.

5.8 Homeotechnology as part of an Environmental Culture

How should we assess the ‘rescue potential’ of homeotechnology in light of the aforementioned considerations? I have tried to demonstrate that, on the normative level, the difference between allotechnology and homeotechnology is not as black and white as Sloterdijk pretends; both can have a positive as well as a negative impact on nature. However, this does not alter the fact that our growing understanding of nature’s own principles of operation offers specific opportunities for a more peaceful co-existence of humans and nature. How to ensure that homeotechnology will live up to its potential for nature-friendliness? In my view, the question of whether homeotechnology will contribute to a more sustainable future largely depends on the broader framework within which it is implemented. This has been argued by Val Plumwood, for instance. Had Plumwood been familiar with the work of Sloterdijk, she would have asked him: “In what political and social circumstances could [homeotechnological] solutions be stable and effective?” (Plumwood 2002, 8). In the following, I will describe how, in Plumwood’s view, modern technoscience must change in order to become part of a society that is “ecologically rational”. As a detailed analysis of her work is beyond the scope of this paper, I will merely present some key elements of her thoughts as a tool for assessing and coming to terms with Sloterdijk’s ideas.

In her last book Environmental Culture: the Ecological Crisis of Reason (2002), Plumwood explores the origins and cultural illusions that lie behind the contemporary environmental crisis. Like Sloterdijk, she explains the degradation of the Earth’s ecosystems as a result of western culture’s dualistic conception of reality. We human beings situate ourselves not only outside, but also above nature. Thus, we have developed conceptions of ourselves as “belonging to a superior sphere apart, a rational sphere of exclusively ‘human’ ethics, technology and culture dissociated from nature and ecology” (Idem, 100). Plumwood claims that this self-image has made us vulnerable to illusions of
autonomy, service and control. We take the functioning of the ecological systems which support us entirely for granted; they only deserve our attention when they fail to perform as expected. Plumwood sets out to demonstrate the *ecological irrationality* of human–nature dualism. At one time, the old human- and reason-centered culture of the West may have facilitated the dominant culture’s comparative advantage over other more modest and ecologically-adapted cultures on this planet. In the age of ecological limits, however, it has become a threat to our survival.

According to Plumwood, the dualistic approach of the West has also affected our image of the relationship between science and the environmental crisis. Since science has played a key role in exposing and controlling environmental damage, it is often presented as the solution to the ecological crisis. However, “modern technoscience also has an uglier but less remarked face: [it] has contributed to producing the environmental crisis at least as much as to curing it” (Idem, 38):

> “Thus we can link overfishing to fisheries science and fishing technology, land salination and degradation to irrigation and agricultural technology, the disasters of intensive agriculture and genetic engineering to biological, agricultural and forestry science, [...] and transportation, combustion and refrigeration technology to global warming and the ozone hole” (Idem, 38).

To ensure the preservation of our planet, we are in need of alternative forms of science. In fact, Plumwood believes that, at the technological level, we already have the means available to accomplish the changes needed to live sustainably on and with the Earth. Unlike Sloterdijk, however, she argues that technology itself cannot initiate this shift towards peaceful co-existence. Her main criticism on technofix solutions is that they don’t urge us to reconsider our dominant lifestyles and demands on nature, but rather aim to meet these demands more efficiently by means of smarter technology. In Plumwood’s view, “what we need for a viable future is an integrated ‘democratic’ science that is dialogical, non-reductionist and self-reflective – a science that can bring itself and its ends under critical and democratic scrutiny. We need above all an *ethical science*” (Idem, 53). The alternative road proposed by Plumwood “involves a major cultural project with ramifications through many areas beyond science and epistemology” (Idem, 50). Crucial to the project’s success is that we abandon the idea that human life takes place in a self-enclosed sphere called ‘culture’ while non-human life is part of a non-ethical sphere called ‘nature’. We must learn to recognise that all life-forms are situated in culture as well as in nature.

How do we shape ethical forms of science? Plumwood advises us to take *Care models of knowledge* as an example. Because such models empower ethical and socially engaged perspectives, they allow us to move beyond the knowledge dualisms rooted in Enlightenment empiricism. Plumwood explains that, up to now, the formal articulation of these models has only been partial. Unfortunately, she herself only offers a few suggestions on how to develop them further. One option would be to confront scientists with genres of writing in which non-human nature is assigned an active, rather than a passive role, for instance the nature writing of Annie Dillard (1945), or “Aldo Leopold’s encounters with thinking mountains” (Idem, 54). In Plumwood’s view, imaginative literature “can help us retell the mechanistic narratives told by reductionist science in more memorable, more generous and more helpful ways” (Idem, 54). Anthropology could also play a role. Plumwood explains that in recent years, this field has been challenged greatly to rethink the subject/object model and to switch to a “model in which knowledge is based on the consenting and cooperative disclosure of other active subjects, and which carries an ethic of care for, and attention and accountability to those who are studied” (Idem, 54). All these recommendations build on the basic conviction that in order for new nature-friendly technologies to be successful, we must change our basic attitude towards nature as well.
5.9 Conclusion

Although I appreciate the evocative and inspiring way in which Sloterdijk fleshes out the potentials of homeotechnology for realising a more sustainable future, I agree with Plumwood that the transition towards ‘nature-friendly’ forms of technoscience will not be effectuated by the emergence of biomimetic forms of knowledge and technology as such, but presupposes, and must be supported by, a broader cultural transformation in which technoscientific developments as outlined by Sloterdijk can become firmly embedded.

Yet, this does not mean that I side with Plumwood against Sloterdijk or vice versa. Rather, I think both perspectives can and should be combined, as their strengths and weaknesses tend to mirror each other. Whereas Sloterdijk tends to overestimate the ‘rescue potential’ of homeotechnology, he does provide a positive notion of what technology could afford, built on a well thought through notion of the role of technology in human nature. Plumwood on the other hand, tends to underestimate or neglect the sustainability potential of modern technoscience. Yet she passionately reminds us of the notion that we should somehow resist merely technological fixes. And although I agree with Plumwood that, in itself, technoscience cannot initiate the shift towards a peaceful co-existence of humans and nature, I agree with Sloterdijk that the technological turn we witness today is itself already a result of the way in which we are changing our lives. By confronting us not only with nature’s genius, but also with our dependency on a healthy biosphere, modern technoscience urges us to embrace more humble and subservient approaches to nature.

References


Conclusion
Transition time
The question society wants answered is not how to be right, but how to be smart – how to go on doing what it has been doing, without paying the price.

– Neil Evernden, 1993

6.1 Between ‘old’ and ‘new’ approaches to nature

In the concluding section of the preceding chapter, I argued that the shift towards a more peaceful co-existence between humans and (the rest of) nature will not be brought about by the emergence of homeotechnology as such. Drawing on the writings of Val Plumwood, I maintained that this transition presupposes, and must be supported by, a broader cultural transformation in which technoscientific developments as outlined by Peter Sloterdijk can become firmly embedded. At the same time, however, the homeotechnological or ecotechnological turn we witness today is itself already the result of the ways in which we are changing our lives (cf. Sloterdijk 2009a); the emergence of ecological genomics and other ecotechnologies demonstrates that we are in a process of ‘re-inventing’ our relationship with nature. The desire to develop technological devices that do not disturb or interfere with the dynamics of nature, but instead seek to mimic nature’s strategies, results from the “growing understanding that it cannot go on like this” (Idem, 699).

In this thesis, I have used ecological genomics as a case study to reflect on the promises of ecotechnology. As ‘ecotechnology in practice’, this field of research not only endorses the expectations concerning the potential of ecotechnology for realising a more sustainable future, but also shows the difficulties entailed in the transition towards a new relationship with nature. I have concentrated on the following research question: To what extent does ecological genomics discourse, as an exemplification of the ecotechnological turn, reflect the possibility of a new relationship between humans, technology and nature? This
In the following sections, I will present the main conclusions of this thesis, starting with a review of the promises entailed in ecological genomics discourse. In spite of the promise of bringing about a new bond between humans, technology and nature, ecogenomics still strongly reflects an instrumental outlook on nature. Next, I will show that ecogenomics discourse also reveals a different, more humble story of nature, albeit as an undercurrent. Finally, building on the work of Val Plumwood, this thesis closes with the consideration that, to protect ecological genomics and other ecotechnologies from becoming channels of a reductionist and instrumental mode of thought, they must be integrated in a ‘democratic’ science that sees both human and non-human nature as a partner in the production of knowledge.

6.2 Reviewing the ecogenomics promises

In chapter 2, I critically reflected on the promise that ecological genomics will bring about a marriage between disciplines that are rooted in different, or even hostile, research traditions (promise 1). As field-based ecological research, and laboratory-based genomic investigations traditionally occupied different areas within the biological sciences, ecological genomics is presented as a field of research that will lead to a whole new way of looking at natural systems. Ecological genomics promises to undermine the deterministic, reductionist approach of laboratory culture; by enabling the exploration of both phenotypic biodiversity and genome diversity, the field lays the foundation of a more holistic approach to the analysis of ecosystems (cf. Kemperman et al. 2010, 3224; Van Straalen & Feder 2012, 4). I have shown that the two approaches at the core of ecological genomics have already taken some important steps towards such a new approach. Thanks to the introduction of next-generation sequencing methodology, the organism-centred approach has succeeded in applying genomic tools to ecologically interesting species, such as reptiles, amphibians and birds. These species are not “selected on the basis of particular genetic and developmental features […] and for ease of growth in the laboratory” (Jackson et al. 2002, 409), but because of their ecological or evolutionary importance and their applicability to...
ecological questions. The metagenomic approach enables the study of microbial communities in their native habitats, rather than in controlled laboratory settings. Thanks to this move from lab to field, metagenomics has provided “access to environmental communities in their whole complexity” (George et al. 2010, 121).

Despite these promising developments, we can still observe a tension between reductionist and more comprehensive approaches to nature. In the ecogenomics marriage, genomics is still the dominant partner. This applies especially to the organism-centred approach, which continues to study its new ecological models in the laboratory. The artificial environments created in labs lack the unpredictability and variability of natural ecosystems, even if they are studied with the “right” model (cf. Kohler 2002). Furthermore, in understanding ecosystem processes, both the organism-centred and the metagenomic approaches are mainly interested in the genetic mechanisms underlying critical ecological interactions. The ‘genomic language’ at the heart of ecological genomics tends to push aside other narratives that aim to describe nature in general, and complex ecological processes in particular.

In the third and fourth chapter, I explored the ambivalence between the societal and ecological promises in ecogenomics; the field will enable us to meet human needs (promise 2), while at the same time respecting the integrity of ecosystems (promise 3). Yet, ecological genomics discourse reveals a tension between these two promises; the wish to exploit the field’s potential for useful applications threatens to undermine the ecological promise. In chapter 3, I ‘zoomed in’ on the first Dutch National Ecogenomics Day to show that the difficulty of integrating societal and ecological goals is symptomatic of quite a fundamental difference between the various parties active in this area. I argued that the turmoil caused by Bram Brouwer’s presentation did not merely reveal a strategic conflict about the field’s (future) research direction; by using the term ‘nature mining’, Brouwer unintentionally exposed that the members of the Dutch ecogenomics community endorse different, even conflicting conceptions of nature. The term is part of a vocabulary that emphasises the beneficial ‘goods’ produced by nature. Whereas part of the audience saw no harm in this commodification of nature, others had difficulties with the reduction of nature to a reservoir to be exploited using the latest technologies.

The inaugural ecogenomics meeting took place in February 2008. Considering how the Dutch ecogenomics field has developed over the past few years, we must conclude that ecogenomics discourse still strongly reflects an instrumental outlook on nature. In the BE-Basic programme (i.e. the foundation of which ECOINC became part in 2010), nature is presented as a resource for unrestricted use. Instead of ‘nature mining’, function-driven metagenomics is now referred to as ‘DNA-mining’. Moreover, the study of nature is described in terms of hunting: “Nature will be the main hunting ground for [uncovering] novel enzymes with very special properties.”

The treasure quest narrative, used internationally to illustrate the metagenomic practice of uncovering the Earth’s microbial diversity, also endorses an instrumental approach to nature. As has been argued in chapter 4, this narrative self-presentation seeks to underline the genius of nature’s innovations; nature appears as a super-innovator whose creations we can incorporate into our own technologies. Nevertheless, nature is still presented as a resource; emphasis is put on the ‘goods’ – antibiotics, vitamins, enzymes – hidden in the soil. Comparing microbial ecosystems to treasure troves reduces the world of microorganisms to “another material thing that can be utilized by humans” (Evernden 1993, 24).

6.3 A different story of nature

But this is not the only story ecological genomics has to tell: the discourse also reveals a more humble and respectful attitude towards nature, albeit (still) as an undercurrent. This undercurrent was for instance revealed by the already mentioned discomfort the term ‘nature mining’ evoked by part of the Dutch ecogenomics community. As I have argued in chapter 3, this unease has been most clearly expressed by Joop Ouborg, who maintained that the term ‘nature mining’ as such conveys a technocratic and human-centred image of nature. It echoes the question: how can we exploit nature to meet human needs? (Ouborg, interview, September 2012). Furthermore, this more humble attitude towards nature is reflected in the ESF-funded projects ensuing from the fundamental research programme of PEEG. Compared to the BE-Basic programme, these projects express a more modest vocabulary, underlining the knowledge rather than the ‘goods’ hidden in nature.

Of the two approaches at the core of ecological genomics (i.e. the organism-centred and the metagenomic approaches), metagenomics most strongly encourages an instrumental outlook on nature. This clearly has to do with its huge potential for useful products and applications. But this potential could also function as a basis for respect; metagenomics confronts us with our dependency on microbes in meeting agricultural, medical and industrial needs. Microbial communities – notably those residing in the soil – play a crucial role in the health and productivity of crops and in cleaning up contaminated environments. Moreover, they are essential for purifying drinking water and the development of new medicines (cf. Handelsman 2007; Committee on Metagenomics 2007). Thus, rather than comparing the Earth’s microbial diversity to a treasure trove or (gold) mine, the metagenomic approach might also urge us to embrace an image of nature which connects with the mythical image of the Earth as a nurturing mother (cf. Merchant 1989).

Metagenomics not only shows us that humans are “as dependent on a healthy biosphere as other forms of life” (Plumwood 2002, 99); another way in which this approach could support more humble attitudes towards nature is by revealing the interdependence of all life forms. By demonstrating how genes “influence each other’s activities in serving collective functions” (Committee on Metagenomics 2007, 13), the field might persuade us to further develop the image of land as a ‘collective organism’, as proposed by Aldo Leopold. The Committee on Metagenomics has already moved in this direction by defining the metagenomic approach as the “genomics of Gaia”, and by referring to the biosphere as “a single superorganism” (Idem, 139). In this particular vocabulary, nature is interpreted differently than in the treasure trove and mining terminology. Although to some scientists, the Gaia concept might be (even) more problematic than the terminology just mentioned (cf. Doolittle 1981), the Earth and its biospheres appear as a significant and meaningful order.

The emergence of a vocabulary in which nature appears as something ‘broader’ than mere commodity-production can also be found in other examples of ecotechnology. In chapter 4, we have seen that Janine Benyus describes the ecotechnological practice of biomimicry as a tutorial practice (cf. Benyus 2002, 4). In order to do justice to nature’s own creative processes, argues Benyus, we should “view nature as a source of ideas instead of goods.” By introducing this alternative narrative, she distances herself from interpretations of the ecotechnological turn that (implicitly) support the conviction that “the world was put here exclusively for our use” (Idem, 8). To enable more respectful approaches to nature, it is not enough to recognise the excellent quality of the ‘goods’ produced by nature, nor will it suffice to see nature as a super-innovator; it requires that we start looking differently at ourselves as well. The recognition of nature as our mentor implies that we simultaneously recognise ourselves as nature’s students,

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80 According to Doolittle, evolutionarily speaking, organisms cannot work for the distant benefit of a vague collective entity. Notwithstanding his opposition to the notion of Gaia, Doolittle is one of the proponents of the concept of ‘metaorganism’ (cf. O’Malley & Dupré 2010, 193).

open to the lessons that nature has in store for us. Although Benyus does not draw attention to the fact that not only nature’s goods, but also her wisdom can be used in a reductionist and instrumental fashion, the alternative view proposed by her reflects the willingness to develop a new, more humble story of nature.82

6.4  Change your narratives!

How to accomplish that this more humble story of nature does not remain an undercurrent, but becomes mainstream? In other words: how can a new relationship between humans, technology and nature be achieved, and how can ecotechnologies such as ecological genomics contribute to this? In my view, a necessary step in this process is that we acknowledge that ecotechnologies are not the whole answer, but only a portion of the answer. This has also been one of the key messages of chapter 5, in which I critically reflected on the ‘rescue potential’ of homeotechnology, as put forward by Peter Sloterdijk. One of Sloterdijk’s basic assumptions is that the ability to incorporate nature’s basic operating principles – replication, selection, transgenesis – into our own technologies is inextricably bound up with an attitude towards nature that no longer strives for mastery and domination. Using metagenomics as an illustration, I have argued that mere technological or instrumental forms of co-operation with nature might also ‘fuel’ our will to power, our will to control living nature; precisely by uncovering nature as a domain of complexity and sophistication, metagenomics opens up new prospects for exploitation, for instance by means of genetic manipulation and ‘nature mining’.

Drawing on the work of Val Plumwood, I concluded chapter 5 with the position that the question of whether homeotechnology will live up to its potential for sustainability or ‘nature-friendliness’, is not a matter of more knowledge or more technology; the homeotechnological or ecotechnological turn demonstrates that on the technological level, we already have the means to accomplish the changes needed to live sustainably on and with the Earth. Yet, ecotechnologies only touch a certain range of problems (cf. Plumwood 2002, 6); these technologies must become part of a broader cultural transformation. I will conclude this thesis by elaborating Plumwood’s thoughts a little bit further, and by reflecting on their meaning for ecological genomics and other ecotechnologies.

Because of its leading role in exposing environmental damage as well as in counteracting it, science is often presented as “the ally and saviour of the environment” (Idem, 8). Plumwood argues that this one-sided presentation of the relationship between science and the ecological crisis is based on our tendency to overvalue and overestimate human technological ingenuity. We only draw attention to the ‘heroic’ role of science, and “vastly underestimate [its] potential for negative impacts on us and on the more-than-human world” (Idem, 239). Plumwood understands the damaging effects of technoscience as a result of its “excessive intimacy” (Idem, 39) with capitalism. She argues that “economic rationalism and productivism ensure that the research directions of technoscience are increasingly dominated by the narrowly instrumental and productive goals of corporations, rather than by broader and more integrated knowledge agendas” (Idem, 39). In chapter 3, I explained that over the past few years, the Dutch ecogenomics community – to the great dissatisfaction of some of its members – has been under pressure to shift its research emphasis from ‘Publication to Product’; due to new funding schemes, the ecogenomics agenda has been increasingly determined by “innovative aspects and valorization opportunities” (Brouwer 2008, 2). Using the terms of Plumwood, “more basic research [has been] neglected in favour of crudely instrumental and productivist goals” (Plumwood 2002, 40). As we have seen, a risk inherent to this focus on market opportunities is that nature is reduced to a passive resource, open for the taking. But Plumwood also points at

82 This comment also applies to the programme of PEEG, which emphasises the knowledge rather than the ‘goods’ hidden in nature.
another danger of this instrumental research direction:

“The dominance of the economic sphere over other spheres means that scientific research and warning systems that have a potentially corrective role in the ecological crisis have themselves been largely compromised” (Idem, 40 – my emphasis).

Applied to ecological genomics, this insight means that the field’s potential to contribute to a more sustainable relationship between humans, technology and nature, risks being sacrificed for the sake of production goals; whereas ecological genomics could play a corrective role in the ecological crisis, the field must be careful not to display complicity to the environmental problems we are facing today. Plumwood’s reflections on the ties or ‘closeness’ between science and capitalism also show us that a marriage between ecology and genomics is not necessarily desirable. The tensions between ecology and genomics are an expression of different ways of being-in-the-world (and, as has been shown in the intermezzo, of different ways of being-in-the-language). Traditionally, ecology refers to the science of the relationships of living organisms to their environments, and the practice of paying tribute to this complex web of life. In the ecogenomics marriage, the objective to fully understand these relationships threatens to be superseded by the societal promises and expectations – i.e. the promisomics (Chadwick & Zwart 2013, 1) – of genomics. By integrating ecology with genomics, the ‘eco’ of ecology might become part of quite an instrumental (or ‘economic’) story of nature.

To protect ecological genomics and other ecotechnologies from becoming spokesmen of a reductionist and instrumental mode of thought – or, to speak with Benyus, from being used “in the ongoing campaign against life” (Benyus 2002, 8) – they must be integrated in a ‘democratic’ science which is based on a dialogical, rather than a dualistic paradigm. Plumwood explains that such a science is not confined to “rational objects of knowledge” (Plumwood 2002, 50), but includes the entire “material and sensory world of nature” (Idem, 47).

In other words: democratic forms of science see both human and non-human nature as a partner in the production of knowledge (cf. Mathews 1991).

“The dialogical paradigm stresses […] communicative methodologies of sensitive listening and attentive observation, and of an open stance that has not already closed itself off by stereotyping the other that is studied in reductionist terms as mindless and voiceless” (Plumwood 2002, 56).

The transition from a dualistic to a dialogical paradigm is not only a task of scientists, but “involves a major cultural project with ramifications through many areas beyond science and epistemology” (Idem, 50). Crucial to the project’s success is that we develop narratives that situate all life-forms – i.e. both human and non-human life – in culture as well as in nature: “We can no longer retain the comfortable human-centred illusion of separate casts of characters in separate dramas” (Idem, 52).

We are all in the same boat (cf. Sloterdijk 1995). A similar message can be found in the work of Freya Mathews, who claims that “[i]t is in fact important that we try to get rid of the distinction between environmental and other ends, or environmental and other contexts” (Mathews 2011, 371); there is nothing beyond the environmental context. With this thesis, I wish to encourage ecological genomicists and other ecotechnologists to incorporate this message in their narratives of nature.

“Should we, in the context where we have the possibility of developing a more generous narrative and dialogical form of rationality that allows more sensitivity to the other, bend and strain our reasoning faculties to keep our options confined to the old reductive models?” (Plumwood 2002, 61).
References


Fantasia. 1940. Film. Dir. Walt Disney. Burbank (CA): Walt Disney Productions.


NGI Annual Report. 2002. “There still is a great deal of pioneering to be done, interview with Prof. dr Bram Brouwer”. Nederlandse Organisatie voor Wetenschappelijk Onderzoek.


How can we accomplish the changes needed to live sustainably on and with the Earth? Today, few other questions seem to have such urgency. Because of its crucial role in exposing environmental damage as well as in controlling it, technoscience is often presented as the solution to the ecological crisis. Looking at recent developments in the life sciences, its contribution to achieving the required changes seems very promising indeed. Confronted with the vulnerability of planet Earth, we seem to have entered a new technological era, in which we are ‘re-inventing’ our relationship with nature. Whereas more traditional technological approaches tend to counteract the dynamics of nature, new technological approaches are increasingly inspired by nature’s own design principles. The desire to produce technological devices that mimic the natural world as closely as possible reveals an ‘ecotechnological turn’, meaning that nature’s own evolutionary strategies provide the models for our innovations.

This thesis critically reflects on the opportunities offered by ecotechnologies to bring about a new, more sustainable relationship between humans, technology and nature, by concentrating on a particular case study: ecological genomics, sometimes abbreviated to ecogenomics. This research field not only gives a clear account of the potential of ecotechnology for a more sustainable future, but also shows the difficulties of the transition from ‘old’ to ‘new’ approaches to nature. The research question addressed in this thesis is as follows:

*To what extent does ecological genomics discourse, as an exemplification of the ecotechnological turn, reflect the possibility of a new relationship between humans, technology and nature?*

This overarching question contains a number of sub-questions, such as: What exactly are the promises entailed in ecological genomics discourse? How can a new relationship between humans, technology and nature be achieved and how can ecological genomics contribute to this?
These questions are answered by analysing self-presentations and self-understandings of ecological genomics as articulated in scientific publications, programmatic documents, research proposals, conference talks, etc. These reveal a number of tensions, circling around three promises.

1. A scientific promise: ecological genomics will bring about a marriage between genomics and ecology.
2. A societal promise: ecological genomics has great potential for serving agricultural, medical, industrial and other societal needs.
3. An ecological promise: ecological genomics will meet these needs in more intelligent, sustainable, and even ‘natural’ ways.

In addition to the analysis of ecogenomics discourse, this thesis explores how the ecotechnological turn has been addressed in philosophical discourse. How have (contemporary) environmental thinkers reflected on the kinds of promises and tensions at the heart of ecological genomics and other ecotechnologies? This second step ‘zooms in’ on the work of a number of thinkers who have studied the relationship between science and technology and the ecological crisis, notably the Australian eco-feminist Val Plumwood (1939-2008) and the German philosopher and cultural theorist Peter Sloterdijk (1947).

The two types of discourses unfold in four papers (from now on referred to as chapters 2 to 5), which constitute the core of this thesis. After having introduced the research themes of this thesis in chapter 1, chapter 2 starts with an exploration of how the ecological genomics research field evolved. How were the most important pillars of ecological genomics set up? Which publications played a key role in establishing the principles of the field? The main purpose of this chapter, however, is to reflect on the promise that ecological genomics will bring about a marriage between field-based ecological research and laboratory-based genomic investigations (promise 1). As ecology and genomics traditionally occupied different areas within the biological sciences, this integration is expected to lead to a whole new way of looking at natural systems; ecological genomics promises to undermine the deterministic, reductionist approach of laboratory culture, and to lay the foundation of a more holistic approach to the analysis of ecosystems. This promise is assessed by an exploration of how ecology and genomics are integrated in the two approaches that currently dominate this field: the organism-centred and the metagenomic approaches. Whereas the former aims to improve our understanding of ecosystem functioning by focussing on the level of the individual (model) organism, the latter concentrates on (the metagenome of) entire microbial communities composed of a variety of species. The organism-centred and metagenomic approaches have already made important progress towards bridging the gap between ecology and genomics. Thanks to the introduction of next-generation sequencing methodology, the organism-centred approach does not need to stick to classical laboratory-based model organisms like Arabidopsis and Drosophila anymore; instead, it now proves to be able to apply genomic tools to ecologically interesting species, i.e. species that provide insight in critical ecological interactions, such as reptiles, amphibians, and birds. The metagenomic approach allows the study of microbial communities in their native habitats, rather than in controlled laboratory settings. Thanks to this move from lab to field, metagenomics has enabled the study of microbial DNA under nature’s own conditions.

In spite of these promising developments, genomics still appears to be the dominant partner in the ecogenomics marriage. This applies especially to the organism-centred approach, which continues to study its (new) models in the laboratory. The artificial environments created in labs lack the unpredictability and variability of natural ecosystems, even if they are studied with the “right” model. Furthermore, in understanding ecosystem processes, both the organism-centred and metagenomic approaches are mainly interested in the genetic mechanisms underlying critical ecological interactions. The ‘genomic language’ at the heart of ecological genomics tends to overshadow other narratives that seek to describe nature in general, and complex ecological processes in particular.
Chapters 3 and 4 concentrate on the ambivalence between the societal and ecological promises in ecogenomics; the field will enable us to meet human needs (promise 2), while at the same time respecting the integrity of ecosystems (promise 3). Yet, ecogenomics discourse reveals a tension between these two promises; the desire to exploit the field’s potential for useful applications threatens to undermine the ecological promise. ‘Zooming in’ on a case study from the Dutch ecogenomics field, chapter 3 shows that the difficulty of integrating societal and ecological goals is symptomatic of quite a fundamental difference between the various parties active in this area. During an important inaugural meeting, Bram Brouwer, director of one of the most sizeable Dutch ecogenomics centres, gave a presentation in which he introduced the term ‘nature mining’. Part of the audience immediately embraced the term, but others had major reservations. This mixed response is generally explained as a culmination of growing tension about the future direction of the field: due to new funding schemes, a shift had occurred from fundamental research to research more interested in ‘valorisation’. However, as put forward in this chapter, the turmoil caused by Brouwer’s presentation did not merely reveal a strategic conflict about the field’s research direction; by using the term ‘nature mining’, Brouwer unintentionally uncovered that the members of the Dutch ecogenomics community endorse different, even conflicting conceptions of nature. The term is part of a vocabulary that emphasises the beneficial ‘goods’ produced by nature. Whereas part of the audience saw no harm in this commodification of nature, others had difficulties with the reduction of nature to a reservoir to be exploited using the latest technologies.

In chapter 4, the normativity hidden in particular stories of nature is explored in more detail. To illustrate how ecotechnologies can be distinguished from more traditional approaches to nature, scientists make use of different narrative structures, metaphors, and images. With these narrative self-presentations, they seek to explain and legitimise their research activities. This chapter concentrates on two of these ‘narratives of ecotechnology’. Firstly, metagenomics researchers compare the practice of uncovering the Earth’s microbial diversity with a quest for a treasure. This narrative is meant to draw attention to the wealth of products yet to be discovered in nature: the ecotechnological turn is presented as a quest for the ‘goods’ nature has produced in the process of evolution. However, there are also more critical voices claiming that the treasure quest narrative does not provide a full picture of what is at stake in ecotechnology. One of them is the natural science writer and innovation consultant Janine Benyus (1958). To do justice to nature’s own creative processes, Benyus argues, nature should be presented as a source of ideas rather than goods. She expresses this alternative view by referring to the ecotechnological practice of ‘biomimicry’ as a tutorial practice. To enable more respectful approaches to nature, it is not enough to recognise the excellent quality of the ‘goods’ produced by nature, nor will it suffice to see nature as a super-innovator; it requires that we start looking differently at ourselves as well. The recognition of nature as our mentor implies that we simultaneously recognise ourselves as nature’s students, open to the lessons that nature has in store for us.

Although Benyus presents the tutorial relationship as the opposite of the practice of treasure hunting, these two narrative self-presentations are strikingly similar in one respect: they were chosen because they are believed to provide sympathetic models with strategically useful, positive connotations only. The treasure quest narrative stresses that, although the development of ecotechnology will require full commitment and high investments, these sacrifices will result in a great material reward in the end, in the form of new products beneficial to humans (e.g. antibiotics, vitamins, enzymes). The tutorial narrative also comes with a positive promise: if we listen carefully to nature’s lessons, we will ourselves become smarter and better problem solvers, as well. Here, the ‘prize’ is not so much a material, but rather an intellectual reward. Yet, both the treasure quest and the teacher-student narratives are much more ambivalent and multidimensional than the scientists using them seem to realise. They are embedded in broader cultural narratives to which they (implicitly) refer and from which they derive their motivational force. Using popular film as an illustration, this chapter shows the moral
ambivalence of both ecotechnological narratives. Whereas reflecting on Raiders of the Lost Ark (1981) helps us to understand what is at stake in presenting ecotechnology as a treasure quest, Disney’s The Sorcerer’s Apprentice (1940) shows the moral ambivalence of the teacher-student narrative.

In chapter 5, ecogenomics discourse is put aside for a moment, to explore how the ecotechnological turn has been addressed in the philosophical writings of Peter Sloterdijk. To emphasise how ecotechnologies can be distinguished from more traditional technological approaches to nature, Sloterdijk draws a distinction between allootechnologies and homeotechnologies. Whereas the former are based on principles that are different from, and often disturb or interfere with the dynamics of nature, the latter seek to act and think in accordance with nature’s own modus operandi. In this chapter, it is argued that Sloterdijk’s reflections on homeotechnology are based on a series of problematic assumptions; Sloterdijk not only claims that homeotechnology is founded on an imitation of nature, but also assumes that the ability to incorporate nature’s basic operating principles – e.g. replication, selection, transgenesis – in our own technologies is inextricably bound up with a co-operative, domination-free attitude towards nature. However, the conviction that we (already) understand nature’s principles of operation sufficiently to imitate them seems fairly hubristic. Moreover, it presupposes that nature reveals itself in a particular way, namely as an assembly line of biomolecular processes. Even if we assume that at some point we will succeed in imitating nature’s most complex and refined processes, this does not automatically preclude domination. Rather, ‘doing it nature’s way’ opens up new prospects for exploitation, for instance by means of genetic manipulation and ‘nature mining’. What is more, since technoscience obscures the classical distinction between ‘biomachines’ and ‘manmade machines’, this exploitation runs the risk of becoming increasingly subtle and invisible. Thus, homeotechnology may result in strengthening our control over nature even on a molecular level. Building on the work of Val Plumwood, this fifth chapter concludes with the consideration that the question of whether homeotechnology will contribute to a more sustainable future largely depends on the broader framework within which it is implemented.

In the concluding chapter 6, it is argued that, in spite of the promise of bringing about a new, more sustainable relationship between humans, technology and nature, ecogenomics discourse still strongly reflects an instrumental outlook on nature. This is for example expressed in the treasure trove and mining terminology, in which nature is pictured as a resource for unrestricted use. Yet, ecological genomics discourse also reveals a different, more humble story of nature, albeit (still) as an undercurrent. This undercurrent is for instance shown by the discomfort the term ‘nature mining’ evoked by part of the Dutch ecogenomics community, and by the vocabulary used in some of its fundamental research programmes. The metagenomic approach, which currently mainly supports an instrumental attitude towards nature, also harbours other interpretations of nature as a significant and meaningful order. By confronting us with our dependency on microbes in meeting all kinds of highly important human needs, metagenomics might encourage us to embrace an image of nature which is more connected with the mythical image of the Earth as a ‘nurturing mother’ (cf. Merchant 1989). Moreover, by underlining the interdependence of all life forms, the field might persuade us to further develop the image of land as a ‘collective organism’, as proposed by Aldo Leopold (1949). The Committee on Metagenomics has already taken some steps in this direction by referring to the metagenomic approach as the “genomics of Gaia”. The emergence of a vocabulary reflecting a more respectful outlook on nature can also be found in other examples of ecotechnology, such as biomimicry. Although Benyus does not draw attention to the fact that not only nature’s goods, but also her wisdom can be used in an instrumental and reductionist fashion, the alternative view proposed by her reflects the willingness to develop a new, more humble story of nature.
How to accomplish that this more humble story of nature does not remain an undercurrent, but becomes mainstream? A necessary step in this process is that we acknowledge that ecotechnologies are not the whole answer, but only a portion of the answer. Drawing on the conclusion of chapter 5, this thesis closes with the position that, to protect ecological genomics and other ecotechnologies from becoming spokesmen of a reductionist and instrumental mode of thought, they must be integrated in a ‘democratic’ science that sees nature as a partner in the production of knowledge.
Samenvatting

Hoe kunnen wij de Aarde op duurzame wijze bewonen? Vandaag de dag zijn weinig vragen zo prangend als deze. Omdat wetenschap en technologie een cruciale rol hebben gespeeld in zowel het zichtbaar maken als het bestrijden van milieuschade, worden zij vaak gepresenteerd als het antwoord op de huidige ecologische crisis. Als we recente ontwikkelingen binnen met name de levenswetenschappen in ogenschouw nemen, dan lijkt hun bijdrage in het doorvoeren van de vereiste veranderingen inderdaad veelbelovend. Geconfronteerd met de kwetsbaarheid van de Aarde voor menselijk ingrijpen, staan wij op de drempel van een nieuw technologisch tijdperk, waarin wij onze relatie met de natuur als het ware heruitvinden. Waar meer klassieke technologische benaderingen doorgaans worden gekenmerkt door een tegennatuurlijke tendens – een tendens de dynamiek van de natuur te verstoren en tegen te werken –, laten nieuwe technologische benaderingen zich in toenemende mate inspireren door de ontwerpprincipes van de levende natuur zelf. De opkomst van technieken die met de natuur meewerken en meedenken, onthult een *ecotechnologische wending*, een omslagpunt waarbij de evolutionaire strategieën van de natuur het model voor menselijke innovatie verschaffen.

In mijn proefschrift reflecteer ik kritisch op de kansen van ecotechnieken om een nieuwe, duurzame(re) relatie tussen mens, techniek en natuur tot stand te brengen. Hierbij richt ik mij op een specifieke casus: het wetenschapsveld *ecological genomics* ofwel *ecogenomics*. Deze casus laat ons niet alleen zien hoe opkomende wetenschapsvelden kunnen bijdragen aan een groenere toekomst, maar confronteert ons ook met de obstakels die wij tegenkomen bij de transformatie van ‘oude’ naar ‘nieuwe’ benaderingen van de natuur. In mijn proefschrift staat de volgende vraag centraal:

*In hoeverre reflecteert het ecological genomics discours, als een casus van de ecotechnologische wending, de mogelijkheid van een nieuwe relatie tussen mens, techniek en natuur?*
Deze overkoepelende vraag bevat een aantal sub-vragen: Welke beloftes liggen precies besloten in het ecogenomics discours? Hoe kan een nieuwe relatie tussen mens, techniek en natuur worden verkregen en hoe kan ecogenomics hiertoe bijdragen?

Om deze vragen te beantwoorden, volg ik twee routes. Allereerst analyseer ik het ecogenomics discours zoals het naar voren komt in wetenschappelijke publicaties, programmatische documenten, onderzoeksvoorstellen, etc. Hierin komen spanningen naar voren die aan drie beloftes kunnen worden gerelateerd:

1. **Een wetenschappelijke belofte**: Ecogenomics zal een huwelijk tot stand brengen tussen laboratorium-georiënteerd genomics onderzoek en veld-georiënteerd ecologisch onderzoek.

2. **Een maatschappelijke belofte**: Ecogenomics zal tal van maatschappelijke behoeften vervullen, bijvoorbeeld in de landbouw, industrie en gezondheidszorg.


De twee routes die ik in dit proefschrift volg, worden uiteengezet in vier artikelen (hoofdstuk 2 tot 5). Na de introductie van de onderzoeksthema’s in hoofdstuk 1, besteed ik in hoofdstuk 2 aandacht aan de geschiedenis van ecogenomics. Hoe hebben de belangrijkste pijlers van dit wetenschapsveld vorm gekregen? Welke publicaties zijn bepalend geweest voor de totstandkoming van de beginselen van het veld? Het voornaamste doel van dit hoofdstuk is echter de toetsing van de belofte dat ecogenomics een huwelijk tot stand zal brengen tussen ecologie en genomics (belofte 1). Omdat ecologie en genomics voortkomen uit verschillende domeinen binnen de biologie, belooft de integratie van deze twee wetenschapsvelden een geheel nieuwe kijk op ecosystems te bewerkstelligen; in tegenstelling tot traditionele moleculaire technieken, die slechts een beperkt aantal variabelen gelijktijdig kunnen bestuderen, maakt ecogenomics een gedetailleerde studie van ecosystems mogelijk op zowel micro- als macroniveau. Ik toets deze belofte door te onderzoeken hoe ecologie en genomics geïntegreerd zijn in de twee benaderingen die het veld vandaag de dag domineren. De eerste benadering – in mijn proefschrift aangeduid als de ‘organism-centred approach’ – beoogt ons begrip van ecosystems te verbeteren door zich te concentreren op het niveau van het individuele (model)organisme. De tweede benadering – waar ik naar verwijst als de ‘metagenomic approach’ – brengt het DNA van complete microbiologische gemeenschappen in kaart; de gemeenschap wordt beschouwd als een organism met één gezamenlijk genoom, het *metagenoom*. Ik zal laten zien dat beide benaderingen reeds belangrijke stappen hebben gezet om de kloof tussen ecologie en genomics te overbruggen. De ‘organism-centred approach’, die tot voor kort werkte met klassieke modelorganismen (*Arabidopsis, Drosophila*, etc.), kan zich dankzij de introductie van ‘nex-generation sequencing methodology’ (NGS) concentreren op soorten met een ecologische relevantie, dat wil zeggen soorten die inzicht verschaffen in kritische ecologische interacties. Voorbeelden hiervan zijn reptielen, amfibieën en vogels. De ‘metagenomic approach’ maakt het mogelijk om gemeenschappen van microben te onderzoeken in hun natuurlijke habitat, in plaats van in het laboratorium. Dit is van groot belang, omdat veel micro-organismen niet ‘in vitro’ bestudeerd kunnen worden.

Ondanks deze veelbelovende ontwikkelingen is genomics nog altijd de dominante partner binnen het genomics huwelijk. Dit geldt in het bijzonder voor de ‘organism-centred approach’, die haar nieuwe modellen blijft bestuderen onder gecontroleerde laboratoriumcondities.
Deze missen de onvoorspelbaarheid en variëteit van natuurlijke ecosystemen. Daarnaast is zowel de ‘organism-centred approach’ als de ‘metagenomic approach’ voornamelijk geïnteresseerd in de genetische mechanismen die ten grondslag liggen aan kritische ecologische interacties. Deze ‘genomics taal’ dreigt andere narratieven die complexe ecologische processen willen beschrijven, te overschaduwen.


In hoofdstuk 4 zal de normativiteit die besloten ligt in bepaalde narratieven van de natuur uitvoeriger worden bestudeerd. Om te illustreren hoe ecotechnieken zich onderscheiden van meer traditionele benaderingen van de natuur, gebruiken wetenschappers verschillende narratieve structuren, metaforen en beelden. Met deze narratieve zelfpresentaties willen zij hun onderzoeksactiviteiten niet alleen inzichtelijk maken, maar ook legitimeren. Dit hoofdstuk concentreert zich op twee van deze ecotechnologische narratieve. Ten eerste de schatgraversnarratief, gebruikt door wetenschappers uit het metagenomics veld om hun zoektocht naar het leven in de bodem te illustreren. Deze narratief benadrukt de rijkdom aan producten die nog in de aarde verborgen ligt; de ecotechnologische wending wordt gepresenteerd als een zoektocht naar de ‘goods’ die de natuur in de loop van de evolutie heeft voortgebracht. Maar er zijn ook kritische geluiden die aangeven dat de schatgraversnarratief geen volledig beeld geeft van wat er allemaal speelt binnen ecotechniek. Eén van die geluiden is afkomstig van Janine Benyus (1958), grondlegger van de ‘learning from nature movement’ die bekend staat als *biomimicry*. Als wij recht willen doen aan de creatieve processen van de natuur, dan zullen wij haar moeten presenteren als een bron van ‘ideas’ in plaats van ‘goods’, aldus Benyus. Ze probeert deze alternatieve visie te vatten in het beeld van de natuur als onze leermeester. Een meer respectvolle benadering van de natuur vereist niet alleen een betere kwaliteit van haar ‘goods’ kennen; noch volstaat het om de natuur voor te stellen als een soort ‘superinnovator’. De leermeesternarratief impliceert dat we niet alleen de natuur, maar ook onszelf met andere ogen gaan bekijken, namelijk als leerlingen die zich openstellen voor de wijsheid van de natuur.

Hoewel Benyus de leermeesternarratief presenteert als het tegendeel van de schatgraversnarratief, vertonen de twee zelfpresentaties een
opvallende overeenkomst: ze worden geacht sympathieke modellen te verschaffen met louter positieve, strategisch bruikbare connotaties. De schatgraversnarratief benadrukt dat de hoge investeringen vereist voor de zoektocht naar bodemleven, uiteindelijk zullen resulteren in een grote materiële beloning: een rijkdom aan bruikbare producten, zoals antibiotica, vitamines en enzymen. Ook de leermeesternarratief wordt geassocieerd met een positieve belofte. De prijs is hier echter niet zozeer materieel, maar veel eerder intellectueel van aard: als we zorgvuldig luisteren naar de lessen van de natuur, zullen wij zelf ook slimmere en betere probleemplossers worden.


In hoofdstuk 5 zal ik het ecogenomics discours tijdelijk terzijde schuiven, om te onderzoeken hoe de ecotechnologische wending ter sprake komt in het werk van Peter Sloterdijk. Met Sloterdijks onderscheid tussen traditionele *allo-technieken* en opkomende *homeotechnieken* als uitgangspunt, zal ik de belofte dat ecotechniek een nieuwe relatie tussen mens, techniek en natuur tot stand zal brengen, kritisch onder de loep nemen. Sloterdijk beschrijft het revolutionaire karakter van homeotechnieken met behulp van drie concepten: ze zijn niet alleen gebaseerd op een *imitatio naturae*, maar maken ook een *niet-dominerende* en *co-operatieve* benadering van de natuur mogelijk. In dit hoofdstuk zal ik beargumenteren dat Sloterdijks reflecties gebaseerd zijn op een reeks problematische assumpties. Sloterdijk veronderstelt dat onze kennis van de natuur inmiddels zo ver is gevorderd, dat wij zelfs haar meest complexe en verfijnde principes – replicatie, selectie, transgenese, etc. – in onze eigen technieken kunnen incorporeren.

Getuigt deze overtuiging echter niet van hybris? Bovendien sluit het vermogen om de processen van de natuur na te bootsen, een niet-dominerende houding tegenover de natuur niet per definitie uit; dit vermogen verschaf ook nieuwe mogelijkheden voor exploitatie, bijvoorbeeld in de vorm van genetische manipulatie en ‘nature mining’. Omdat homeotechnieken het klassieke onderscheid tussen natuurlijke en door de mens ontwikkelde technieken vertroebelen, wordt deze exploitatie bovendien steeds subtieler en (daardoor) minder zichtbaar. Homeotechnieken zouden derhalve onze controle over de natuur ook kunnen vergroten. Voortbouwend op het werk van Val Plumwood, besluit dit vijfde hoofdstuk met de overweging dat de bijdrage van homeotechnieken aan een duurzame(re) toekomst in grote mate afhangt van het bredere kader waarbinnen zij worden geïmplementeerd.

In het concluderende hoofdstuk 6 wordt beargumenteerd dat het ecogenomics discours, ondanks de belofte een nieuwe, duurzamere relatie tussen mens, techniek en natuur tot stand te brengen, in sterke mate is gebaseerd op een instrumentele natuuropvatting. Dit komt bijvoorbeeld tot uitdrukking in de schatgraversnarratief en het begrip ‘nature mining’, waarin de natuur wordt voorgesteld als een bron die beschikbaar is voor ongelimiteerd menselijk gebruik. Maar het ecogenomics discours onthult ook een bescheidener benadering van de natuur, zij het (nog) wat aarzelend. Deze onderstroming komt bijvoorbeeld tot uitdrukking in het ongemak dat de term ‘nature mining’ losmaakte bij een deel van de Nederlandse ecogenomics gemeenschap. De ‘metagenomic approach’, die vooral in sterke mate leunt op een instrumentele benadering van de natuur, herbergt ook andere interpretaties van de natuur als een belangrijke en betekenisvolle orde. Door ons te confronteren met onze afhankelijkheid van microben in het vervullen van tal van menselijke behoeften, zou metagenomics ons kunnen aanmoedigen een natuurbeeld te omarmen dat gerelateerd is aan het mythische natuurbeeld van de aarde als ‘nurturing mother’ (*vgl.* Merchant 1989). Door de onderlinge afhankelijkheid van alle levensvormen te benadrukken, zou het veld ons bovendien kunnen stimuleren om Aldo Leopolds beeld van het land als
'collective organism' verder te ontwikkelen (1949). Het Committee on Metagenomics (2007) heeft al een stap in deze richting gezet door naar de metagenomics benadering te verwijzen als “the genomics of Gaia”. De opkomst van een vocabulaire dat een meer respectvolle visie op de natuur uitdrukt, kan ook worden herkend in andere voorbeelden van ecotechniek, zoals biomimicry. Hoewel Benyus geen aandacht besteedt aan het feit dat niet alleen de ‘goods’, maar ook de wijsheid van de natuur voor instrumentele doeleinden kan worden ingezet, geeft haar alternatieve leermeesternarratief blijk van de bereidheid een nieuwe, bescheidener visie op de natuur te ontwikkelen.

Hoe zouden we ervoor kunnen zorgen dat dit bescheidener perspectief geen onderstroming blijft, maar de heersende stroom wordt? Een noodzakelijke stap in dit proces is in mijn optiek dat we erkennen dat ecotechniek niet het gehele antwoord, maar slechts een deel van het antwoord is. Voortbouwend op de conclusie uit hoofdstuk 5, sluit dit proefschrift af met de positie dat, om te voorkomen dat ecogenomics en andere ecotechnieken woordvoerders worden van een reductionistische en instrumentele denkwijze, zij moeten worden geïntegreerd in een democratische wetenschap die de natuur beschouwt als partner in de productie van kennis (vgl. Plumwood 2002).
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Sanne van der Hout (1982) studied Philosophy at Leiden University and Applied Ethics at Utrecht University and the Norwegian University of Science and Technology. During a field trip to South Africa as part of her Applied Ethics studies, Sanne’s love for Environmental Ethics was born. In 2008, she took up a position as a PhD researcher at the CSG Centre for Society and the Life Sciences – called Centre for Society and Genomics at the time – with Prof. dr Hub Zwart and Dr Martin Drenthen as her supervisors. This position, of which this thesis is the result, gave her the opportunity to further specialise in the field of Environmental Philosophy. In addition to her PhD research, Sanne followed a training in Philosophical Counselling at the Vereniging voor Filosofische Praktijk. Sanne lives together with Pieter. In November 2009, their daughter Carice was born, and in February 2013, their son Dorian.

Biography

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