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VISIONS OF GAIA

The role of the organism metaphor in the development of Gaia Theory

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ABSTRACT

James Lovelock's Gaia Theory has historically been a controversial theory. Popular with the countercultures and initially not accepted by the scientific community, Gaia has always bordered on pseudoscience. A fair share of the critiques Gaia has attracted are related to Gaia's central metaphor which likens Gaia to an 'organism'. This organism metaphor has played an important role in the development of Gaia Theory, and this paper shows how the organism metaphor influenced the scientific discourse surrounding Gaia Theory. The organism metaphor opposed the more reductionistic scientific worldviews of the Neo-Darwinists who critiqued Gaia. Moreover, Gaia's organism metaphor allows for contradictory interpretations, and this aspect of the organism metaphor can be seen as an explanation as to why Gaia Theory was simultaneously widely discussed and ridiculed by scientists. Because of its contradictory nature, the organism metaphor is arguably too broad for what Lovelock tries to achieve with it, namely being a spearhead for green movements.

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Introduction

In September 1965, an engineer called James Lovelock was asked to study methods to detect life on Mars. This task laid the foundation for a theory that would live a wildly controversial life: the Gaia Theory. Lovelock supposed that the environment and the life forms on earth had co-evolved in such a way that the negative feedback systems created by them support and perpetuate the conditions for this co-evolved combination. Gaia, which was the name Lovelock gave to this co-evolved entity, was supposed to be seen as a 'superorganism'. Even though the organism aspect of Gaia Theory was intended to be a metaphor, it played a fundamental role in the criticisms Gaia Theory has attracted, and, as this paper argues, has therefore played a fundamental role in the development of Gaia Theory itself too. This paper investigates the role of the organism metaphor in the development of Gaia Theory. It integrates a historical analysis with a philosophical analysis, as is done in the modern field of *integrated history and philosophy of science.*

Chapter 1 will give a brief introduction on Gaia Theory. First, the history of Gaia Theory will be mapped out, both in its academic and public discourse. Gaia Theory has met a lot of varying interpretations and as a result a wide variety of criticisms. Therefore an overview of the different interpretations of the theory must be given, which will follow the history section. After outlining the theory, the historical and contemporary criticisms of Gaia Theory will be discussed, which are grouped under three main lines of criticism for the sake of simplicity: 1) Gaia Theory and its incompatibility with Darwinian Individuality 2) Gaia Theory as pseudoscience 3) Gaia Theory and 'wrong' teleology. All of these lines of criticism are related to Gaia's organism metaphor, which forms the foundation for this paper's research question: "*What role has the organism metaphor played in the development of Gaia Theory?"*

Chapter 2 discusses the organism metaphor in several subchapters. First, philosophical notions on the essence and use of metaphors in science will be introduced and discussed. More specifically, Max Black's *interaction view* of metaphor will be used as the perspective to understand metaphors through. Kostas Kampourakis' *structure-of-metaphor* scheme (SoM-scheme), which is an expansion of Black's interaction view, will be used to investigate a case study on the metaphor of 'natural selection' and what role it has played in the development of evolution theory. This scheme is then used to investigate the role of the organism metaphor in the development of Gaia Theory. With the help of the SoM-scheme, several conclusions can be made. This analysis shows that the organism metaphor lends itself to contradictory interpretations, which has complexified the scientific acceptance of Gaia Theory. It also shows the rhetorical power that the Gaia organism has, and therefore explains its appeal to the public audience.

1. Gaia Theory

1.1 What is Gaia Theory?

Gaia Theory is a scientific theory developed by James Lovelock and later Lynn Margulis. Named after the primordial Greek Goddess of the Earth *Gaia* (Lovelock, 2010), Gaia Theory essentially argues that Earth's biota interact with the Earth's inorganic environment to form a self-regulating system which maintains the necessary conditions for life on Earth. The biosphere should, according to Gaia Theory, have an influence on environmentally regulating factors such as temperature, water salinity and atmosphere composition.

Gaia Theory has developed quite a bit since its conception, as I will show in chapter 1.1.1. For this introduction, I will use a relatively simple contemporary understanding of Gaia Theory (Lenton & Wilkinson, 2003). Other interpretations of Gaia Theory will be given in this paper. Lenton and Wilkinson are earth scientists who are experts in Gaia Theory, and the definition of Gaia Theory they provide can be seen as representative for modern Gaia Theory as Lenton and Wilkinson are prominent contemporary scholars working on Gaia and their tenets do not inherently contradict other 'versions' of Gaia.

Lenton & Wilkinson identify four basic ideas in Gaia Theory:

1) Life alters the environment it exists in.
2) Life, in any form, grows and reproduces.
3) Environmental conditions constrain life.
4) Natural selection occurs.

Lenton & Wilkinson derive a few statements from these ideas. 1 & 2 combined produce global environmental effects. 1 & 3 combined produce environmental feedback. 1, 2 & 3 combined therefore produce global environmental feedback. Since natural selection occurs on Earth, we can argue that global environmental feedback on selection occurs on Earth according to Gaia Theory (Lenton & Wilkinson, 2003).

1.1.1 History of Gaia Theory

Before Gaia Theory, ideas that were similar to it had been presented in the field of earth science, albeit in slightly different forms. The 'father of geology' James Hutton, for example, linked geological and biological processes together when geology started to take shape as a serious science in the early 18th century. More specifically, Hutton argued that geological homeostasis was a result of volcanic activity, which 'repaired' eroded rocks which had sunk in the ocean. Lovelock owes Hutton the idea of a regulating earth, as Lovelock himself has argued that he merely added the role of the biota to the purely physical homeostasis that Hutton proposed (Onori & Visconti, 2012, p. 376). The well-known geographer Alexander von Humboldt also argued that coevolution of the living world and the Earth's surface existed (Capra, 1997). Later, in the early twentieth century, Ukrainian geochemist Vladimir Vernadsky developed a theory which argued that the presence of abundant atmospheric gases, such as oxygen, nitrogen and carbon dioxide, stem from processes in which the biota play a role (Weart, 2005). James Lovelock addresses and acknowledges these influences in his works. Gaia Theory differentiates itself from earlier theories by the assumption that biota *regulate* and create conditions under which the biota can persist. In earlier theories, the processes were merely identified. In Gaia Theory, these processes form a system.

Gaia's name was not conceived by James Lovelock, as one might suspect. Instead, it was proposed by Lovelock's neighbour, the famous novelist William Golding[1]. Golding proposed that Gaia be called Gaia as a reference to *Gea,* which is simultaneously a name for the primordial Greek Goddess of the Earth and a form of the pre-fix *geo,* which geology, geography and environmental sciences use (Latour, 2017, p. 62).

Lovelock's first approximate formulation of the Gaia Hypothesis[2] is in his joint 1965 paper *Planetary Atmospheres: Compositional and other Changes Associated with the Presence of Life*, which Lovelock wrote with C.E. Giffin. This article specifically focussed on the concept of the detection of planets which might support life by studying the chemical composition of their atmosphere (Lovelock & Giffin, 1969). Lovelock had gained inspiration for this paper and other early ideas on Gaia Theory from his work for NASA. Lovelock was asked by NASA to research the chemical and physical composition aspects of Mars' atmosphere. Lovelock, at this time, recognized that the earth's atmosphere was quite unique compared to other planets in the solar system (Deane-Drummond, 1996, p. 3). From *Planetary Atmospheres* onwards, Lovelock started developing the theory in several journal articles, before publishing *Gaia: A new look at life on Earth* in 1979. In the same year, Lovelock published another book length explanation of the thesis, titled *The Quest for Gaia.*

From 1971 onwards, Lovelock was joined in his work on the Gaia hypothesis by the microbiologist Dr. Lynn Margulis. Margulis was an iconoclastic figure in the biological community – she had initially been criticized heavily for her theories on eukaryotic organelles and endosymbiotic theory, which turned out to be right. Her contributions are now widely accepted, but her work on these theories in combination with her advocacy for Gaia Theory have made Margulis a controversial figure (Ruse, 2015, p. 169). Lynn Margulis helped Lovelock in solidifying Gaia Theory towards being defined more clearly – her scientific rigour partially helped erase irregularities and contradictions. She denied and rejected the metaphorical language Lovelock often used. For Margulis, Gaia is not an organism but should be understood as an emergent property of interaction among organisms. The personification of Gaia as a Mother Earth was also rejected by Margulis (Ruse, 2015, p. 19). Margulis would eventually dedicate several chapters of her book *The Symbiotic Planet* to Gaia Theory (Margulis, 2008). Despite Margulis' attempts to scientifically clarify Gaia Theory, she herself has stated that Gaia is more a point of view than a theory, which exemplifies Margulis' holistic worldview through which she rejects reductionistic biology (Onori & Visconti, 2012, p. 384).

Margulis' main addition to Gaia Theory is arguably replacing Lovelock's initial homeostatic essence. Where Lovelock argued that Gaia was an 'organism' which regulates itself towards an optimal homeostatic state, Margulis opted for an autopoietic perspective. Autopoietic systems are systems capable of reproducing and maintaining themselves by creating their own parts and expanding themselves. By viewing Gaia as an autopoietic system, Gaia partially 'lost' the teleological side it was critiqued for. The theory had now acquired the autonomy of a self-referential system.. This differed from the homeostat, as a homeostat inherently implies an engineer who tinkers with the homeostat. In Margulis words, Gaia Theory had become "*The autopoietic planet where the biosphere as a whole is autopoietic, in the sense that it maintains itself. In our view, planet autopoiesis is the aggregate, emergent property of the many gas-trading, gene-exchanging, growing and evolving organisms in it."* (Margulis & Sagan, 2000, p. 30).

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[1] Nobel prize winning-novelist, best known for his novel *Lord of the Flies*.

[2] Initially, James Lovelock called Gaia the Gaia *Hypothesis.* As Gaia started becoming more scientifically debated, the name most scholars used would become Gaia *Theory.* Even though both terms are still used in academic literature on Gaia, I will henceforth use Gaia Theory for the sake of clarity.

After Lovelock and Margulis' initial work, the Gaia Theory started to acquire more widespread attention in both the scientific community and the general public. Michael Ruse, in his book *The Gaia Hypothesis: Science on a Pagan Planet,* states that Lovelock likely made a conscious choice to throw his ideas into the public domain. Scientists were not accepting of Gaia Theory, so he had to look at others who would. The popular public science magazine *The New Scientist* published an article on Gaia in 1975, and from this point onwards Lovelock's language concerning Gaia Theory is significantly less restrained (Ruse, 2015, p. 20). Lovelock saw no problem in discussing the implications of Gaia Theory for other popular scientific endeavours, such as space travel and alien life. Of course, this is hardly surprising given his background as a NASA engineer. Gone was the rigid scientific cage. In 1979, Lovelock called the Great Barrier Reef a "partly finished project" which was being built by the biota, and argued that the biota exploited volcanic eruption for their own needs. Moreover, he spent a fair share of his public time discussing human cognition and Gaia Theory, and argued that Gaia had become self-conscious since humans roamed the earth (Ruse, 2015, p. 24).

As a result of Lovelock's shift to the mainstream and his flirting with the teleology he denied in his scientific works, his scientific critics chose to enter the public arena as well. Lovelock's main critics, the Neo-Darwinists), were already publicly known for their science books for broader audiences. The most famous example of this is Dawkins' 1976 book *The Selfish Gene*. Whereas the scientific community initially completely discarded Gaia Theory, the public loved it. It can be theorized that the "earth as an organism" metaphor struck the right cord at the right time – it provided a 'beautiful' vision of a harmonious nature in the wake of many environmental disasters (Ruse, 2015, p. 37). Left-field scientists began to take hold of Gaia Theory too: Fritjof Capra, writer of *The Tao of Physics,* for example, praised Lovelock and Gaia for its subversions of modern scientific norms (Ruse, 2015, p. 38). Moreover, ecologists and environmental scientists who felt they could not work with the reductionist scientific culture saw in Gaia Theory a holistic framework perfectly fit to their wishes.

This tense playing field between the public and the scientists, between science and pseudoscience, called for a more structured discussion regarding Gaia Theory. Therefore, Gaia Theory became the subject of a couple of 'Gaia Conferences', in which biologists, earth scientists, environmentalists and philosophers discussed Gaia Theory. Criticisms against Gaia Theory were raised, which forced Lovelock, Margulis and contemporary scholars working on Gaia Theory to further develop their exact thoughts and work out contradictory aspects of Gaia Theory. Therefore, these conferences became the origin of some important developments in Gaia Theory. One of the most famous examples of the regulation types Gaia Theory speaks of, which has sprung from the critiques at the Gaia conferences, is James Lovelock and Andrew Watson's *Daisyworld*-model (Watson & Lovelock, 1983), which will be discussed further in this section.

In total, four Gaia conferences took place. The first, which was named *Is The Earth A Living Organism?* took place in 1985 at the University of Massachusetts and was relatively small, yet was attended by a surprisingly wide variety of scholars. Among the speakers were Lovelock himself, environmental philosopher David Abram, poet John Todd and Nobel prize winner George Wald. Sponsored by the environmental organization *the National Audubon Society,* the conference can be seen as the first formalized discussion on Gaia Theory in the scientific community. The second Gaia conference, held in 1988 in San Diego, California, was more widely attended and meant more for the development of Gaia Theory. Organized by climate scientist Stephen Schneider, the conference widely discussed many aspects of Gaia Theory such as its relation to ecology, biology, biochemistry and astronomy. David Abram again talked about metaphors in Gaia and their influence in science (Kauffman, 1988). The most important speaker at the Chapman conference was perhaps James Kirchner, a contemporary earth scientist. Kirchner argued that Gaia Theory was not consistent throughout its formulations, and that

Lovelock and his contemporaries should clarify which kind of Gaia they were talking about. Every variation of Gaia carried different implications, and a fruitful scholarly debate could not be had without consistent definitions (Kirchner, 1989). In the next chapter, *Versions of Gaia,* I will discuss this further. The second Gaia conference had been a massive boost to Gaia Theory's scientific formulations, after which Gaia Theory started gaining scientific attraction. Therefore, the third Gaia Conference was no longer primarily about *how* one should talk about Gaia Theory or whether Gaia Theory is teleological, but instead about the mechanisms in Gaia Theory (Ruse, 2015, p. 217). The third conference was named the Second Chapman Conference, and was held in 2000 in Valencia, Spain. It discussed to what degree *Daisyworld* was representative for a situation on earth, and which mechanisms could be seen as Gaian mechanisms. Lovelock started this conference off with a video stating that Gaia was in fact *not* an organism.

Daisyworld

The introduction of *Daisyworld* can be seen as the turning point for Gaia Theory. No longer merely speculative, Lovelock now showed a mechanism that supported Gaia Theory. *Daisyworld* supposed a hypothetical world on which the radiant energy from a star gradually increases or decreases. On this *Daisyworld*, two types of daisy grow: the white petaled and black petaled daises. As a result of their albedo, white petaled daisies reflect light, and black daisies absorb light. Both types of daisy compete and are modelled with regards to temperature-effects on growth-rates. This competition will, in *Daisyworld*, lead to a planetary temperate which approximates the optimal temperature for daisy growth. The model shows that where a abiotic world would linearly rise in temperature with solar output, the biotic *Daisyworld* remains relatively constant (Ruse, 2015, p. 150). Even though Daisyworld was always an oversimplified model of inherently complex planets, it did provide a conceptual backbone to the regulation idea which is essential in Gaia Theory. Regulation here is understood as regulation to sustain climate variables which support the persistence of biota. Examples of these variables are atmospheric compositions, temperatures, acidity and nutrient availability. While the idea of regulation in the environment is not new in itself, Gaia Theory was the first theory to propose regulation from *two* sides: the biota *and* the environment.

The Gaia Theory has proven to be a significant influence on modern ecology, earth science and environmental studies. Lovelocks' *Daisyworld* was quite similar to contemporary ecological models but differed in the regulation aspect – it included feedback between the biota and the abiotic environment. This distinguished *Daisyworld* from models which merely focussed on one field, which were popular at the time of *Daisyworld*'s conception (Wilkinson, 1999, p. 534). Gaia Theory's influence can be seen more clearly in some aspects of ecological theory than in others. The study of biodiversity, for example, is an area which has 'profited' from Gaia Theory. A study by Leaky and Lewin suggests that there are two main ways in which Gaia Theory influenced the modern concept of biodiversity. Firstly, the extrapolation of feedback mechanisms from the ecosystem-level to the global level, as implied in Gaia Theory, suggests a global interconnected biodiversity. Secondly, the discovery of the correlation between population stability and increases in biodiversity can be linked to Gaia Theory. As Gaia Theory helped map out the feedback systems that play key roles in ecosystems and therefore population stability, biodiversity could with Gaia Theory be understood as a result of interconnected ecosystems. *Daisyworld* and Gaia Theory made it apparent that biodiversity was inherently connected to far more factors than initially anticipated (Leaky & Lewin, 1996). Moreover, it can be suggested that Lovelock's *Daisyworld* partially bridged a gap between practical ecologists and mathematical ecologists, as it could both practically and theoretically show that variability increases stability (Rushton, 2008, p. 4).

The field of earth system science has also had one notable innovation to thank Lovelock for: before Lovelock, biologists and Earth scientists mainly kept their respective fields of science separated –

biology and geology happened at different scales and with different processes. Of course, Gaia Theory and *Daisyworld* showed that this separation was quite misguided, and as such Gaia opened up a research field at the intersection of the aforementioned disciplines (Lenton & Wilkinson, 2003).

1.1.2 Versions of Gaia

It is important to realize that over time, different interpretations and formulations of Gaia have existed. These have led to a wide variety of uses and criticisms, which can be confusing to anyone not familiar with the subject. It can be argued that the different interpretations and the lack of clear definitions when Gaia Theory is discussed, have been the root of many controversies and discussions concerning Gaia Theory. James Kirchner, who was present at the first and second Gaia Conferences, suggested that the Gaia Hypothesis should be split into a range of hypotheses. Kirchner identified four main versions of Gaia (Kirchner, 1989, p. 224), which from that publication onwards have often been used by other scholars who were studying Gaia Theory and which I will therefore use to provide a basic understanding of the variety of Gaia interpretations. An important sidenote to make is that the versions Kirchner presented are the 'starting point' for further discussions on different versions of Gaia. There have historically been other interpretations which are not mentioned here[3].

1. Coevolutionary Gaia

Being the most 'simple' form of Gaia Theory, Coevolutionary Gaia implies what had already largely been known in contemporary earth sciences, namely that the biota influences the abiotic environment. The biota is then influenced by the abiotic (and biotic) environment by means of Darwinian selection. Coevolutionary Gaia does not differ much from traditional environmental knowledge in the sense that scientists were aware of the influence of the biota on the environment long before Lovelock (e.g. rock erosion as a result of root growth). This model implies that destabilising models are just as possible as stabilising models. Positive and negative feedback loops are just as likely to exist, and Gaia would show no 'preference' for either of these. Kirchner argues that this hypothesis does not even need to be tested because the Gaia system here is *defined* by its interrelation. Interrelation means that each component affects the other, and therefore there are no options but negative or positive feedback. Therefore, Coevolutionary Gaia can hardly be called radical or scientifically innovating at all, as it follows from basic system analysis and the existence of feedback processes had been discovered before Lovelock.

2. Homeostatic Gaia

Contrary to Coevolutionary Gaia, Homeostatic Gaia assumes that the biota does in fact regulate the environmental conditions of Earth. According to Homeostatic Gaia Theory, the biota and the physical world are dominantly linked through negative feedback loops. This is, arguably the closest interpretation to Lovelock's Gaia. This does not inherently mean that Earth shifts towards an optimal state, merely that there are equilibrium points, which the biota regulates towards. Shifts from one equilibrium to another are possible within this theory and have already happened – the shift from anaerobic to aerobic atmospheric conditions through the biota is an example of this (Deane-Drummond, 1996, p. 6).

This form of Gaia Theory is criticized for precisely its difference from Coevolutionary Gaia. It is easily arguable that living things can be seen as a contributory part of the rheostat system. However, one could imagine such a rheostatic system without life too, as regulating feedback mechanisms have been

[3] Other versions, such as the Neo-Pagan version of Gaia that Michael Ruse discusses in his book *Gaia: Science on a Sagan Planet*, are not mentioned here. This is either because these interpretations are not discussed widely enough to consider for this paper, or because they merely exist in the public discourse and not in the scientific discourse which this paper studies.

found in inorganic systems too. A 'new equilibrium' could therefore just as well exist without living matter, on a planet in which all life has been destroyed. Kirchner calls a process such as this one *anti-Gaian.* Modern Gaia literature partially discards this critique. For example, Lenton & Wilkinson argue that Kirchner misunderstands what a Gaian system is. Gaia, they argue, is a system of feedback loops. Naming a form of feedback which steers towards a different optimum anti-Gaian while it happens *inside* the system Gaia makes little sense, and is according to Lenton and Wilkinson a frequently happening misunderstanding of what Gaia is. A new optimum would just be a 'new' Gaia. They suggest that the terms Gaian and anti-Gaian should be avoided instead, and hereby Gaia would acquire an all-encompassing meaning. The 'new equilibrium' would still exist within the Gaia system, even though the living component of Gaia has perished (Lenton & Wilkinson, 2003, p. 4).

In Homeostatic Gaia, Kirchner distinguishes *two* versions: Weak Gaia and Strong Gaia. The weak hypothesis argues that the dominant interactions in between the biota and abiotic environment are stabilising. In the weak version, a 'Gaian' system with mostly negative feedback loops is likely the result of a 'lucky' Gaia, in which the negative feedback loops are by-products of other processes and not a direct result of life forms exerting their influence on the environment. The stronger form of Homeostatic Gaia argues that these dominant interactions make the Earth's physical environment far more stable than it would have been without these interactions. This version of Homeostatic Gaia is generally not as accepted as the weaker version is (Cazzolla Gatti, 2018, p. 92).

3. Geophysical Gaia

This version of Gaia Theory argues that Gaia itself is in fact a single 'organism' (even though that should still be read as a metaphor), which has coevolved with life and allows the persistence of life. Here, Gaia is a combined entity of the biota and the abiotic environment. No longer are these separate entities influencing each other. Instead, they should be seen as one. Lovelock argued that Gaia 'emerged' with the evolution of photosynthetic organisms. Formulations like Geophysical Gaia show the difference between Gaia and other frameworks to study the earth through:: *"specialties, like biogeochemistry, theoretical ecology, and evolutionary biology, all exist, but they have no more to offer the concerned environmental physician or the patient than could the analogous science of biochemistry or microbiology in the nineteenth century."* (Lovelock, 1998, preface). Kirchner sees this form of Gaia as problematic if it is seen as anything more than a metaphor. Lovelock argues that geophysiology is "*the essential theoretical basis for the putative profession of planetary medicine"* (Lovelock, 1986, p. 12), whilst no further defining this theoretical basis. The organism metaphor might indeed be useful to speculate about ecological 'health', Kirchner argues, but without a scientific foundation Geophysical Gaia becomes unusable (Kirchner, 1989).

Nowadays scholars working on Gaia, including Lovelock, do not really have serious discussions about this form of Gaia anymore. The organism metaphor, upon which this interpretation resides, is now strictly considered a metaphor. Even though it is still used by Lovelock and sporadically by other scientists, discussions do not focus on Gaia as an organism anymore and instead focus on the system Gaia, and whether the regulatory systems Lovelock argues for do indeed exist. As such, Geophysical Gaia is not seen as a serious version of Gaia anymore in contemporary debates, and the metaphor is only sporadically used as an interdisciplinary way to understand the complex processes of the earth . Kirchner states this development as such: *"I would agree with the proponents of Gaia that it may be useful to attempt to speculate about the natural world as if it were an organism. But the question of whether the Earth actually is an organism is neither scientifically meaningful nor scientifically answerable."* (Kirchner, 1989, p. 232).

4. Optimizing Gaia

Optimizing Gaia, the most radical and speculative version of Gaia Theory, postulates that the biota control the physical environment in such a way that *optimal* conditions are created for the biosphere. Optimizing Gaia can be seen as an extension of the Geophysical version: Gaia still is the co-evolved biosphere/environment entity, but now it actively strives towards an optimal state.

This type of Gaia, Kircher argues, is inherently ill-defined. Optimal conditions must, if this Gaia would be under scientific investigation, be defined. A few definitions of optimal conditions have been raised before. One could for example state that the optimal conditions are the current editions, as the current conditions support the current biosphere. This, however, is a tautology: optimality is defined by current conditions, and current conditions are defined as optimal (Kirchner, 1989, p. 232). Another definition would be a teleological one: biota striving towards optimal conditions would require some foresight and planning, which suggests that there is a consciousness behind Gaia (Doolittle, 1981). Kirchner argues in response to Doolittle that there are mechanistic scenarios in which favourable conditions evolve without an 'engineer': ants employ strategies for nest temperature regulation without external instructions (Kirchner, 1989, p. 232). Gaia was initially heavily critiqued for the apparent teleological side of Gaia. It is important to remember that before Kirchner's 'versions' of Gaia, nobody explicitly stated which type of Gaia they were talking about. Therefore, the pre-Kirchner Gaia inherently had a teleological side to it.

As Kirchner himself has said with regards to these 'versions' of Gaia:

> *This wide range of possibilities, along with the engaging plasticity of the terminology, means that individuals can make of Gaia whatever they wish. The unsympathetic can ridicule the notion of global optimal control. The sympathetic can point out that the biota and the abiotic environment are obviously interrelated in any number of ways. ……. And in scientific discourse a great deal of unnecessary argument may result from a simple misunderstanding of which hypothesis is on the table at any given time.* (Kirchner, 2002, p. 225)

The next subchapter discusses the main critiques that were raised against Gaia. It should be understood that, initially, many critiques stem from the 'misunderstandings' Kirchner mentions. The critiques were partially resolved after the second Gaia Conference, in which Kirchner published his 'versions'. For example, nobody considered Gaia as a 'real' organism anymore. Still, these critiques exist on a more fundamental level, and Kirchner's versions mostly made them easier to discuss as there was less semantic confusion.

1.2 Criticism of Gaia Theory

Gaia Theory has been the subject of a wide range of criticisms throughout its existence. This paper discusses the organism metaphor and its role in the development of Gaia Theory. As will be shown, a large share of the critique Gaia Theory has attracted is at least tangentially related to this metaphor, which is why the criticisms need to be mapped out. This subchapter will outline the main criticisms, which historically have been on:

1) Gaia Theory and its incompatibility with Darwinian Individuality

2) Gaia Theory as pseudoscience

3) Gaia Theory and 'wrong' teleology

Lovelock, Margulis and other scholars who have worked on Gaia Theory have engaged in constant debates with regards to these criticisms. This subchapter will map out the discussion between the critics and those who champion Gaia Theory. In reality, criticism of Gaia Theory is not as categorically divided as they seem to be in this section. For example, the critique on Gaia being an 'organism' partially belongs under all sections. For the sake of clarity and readability, I have made a rough distinction between the main criticisms.

1.2.1 Gaia Theory and incompatibility with Darwinian Individuality

Gaia Theory has been widely criticized on the grounds of it not fitting within what is perhaps the most fundamental biological theory, the theory of evolutionary theory. Therefore, scientists who took issue with Gaia Theory could mostly been found in the community that concerned itself with evolutionary theory: fundamental evolutionary biologists (Ruse, 2005, p. 26). Richard Dawkins, perhaps the fiercest Gaia critic and one of the most well-known Neo-Darwinists, took every chance to stress Gaia's Darwinian shortcomings. Reductionism was the way to do biology at the time (Ruse, 2005, p. 88), and postulating a theory which apparently refuted reductionism as much as Gaia did could only lead to a clash, especially given Gaia Theory's popular public reception.

The initial critiques on Gaia Theory from evolutionary biologists come down to two major points:

1) Gaia being alone, thus not being part of a biological population.

2) The fact that Gaia does not reproduce.

The combination of these two points make that Gaia cannot be considered a product of natural selection. Therefore, Gaia cannot be a product of evolution, as these characteristics of Gaia are fundamentally in contradiction with traditional Darwinist thought. Since an organism is, in evolutionary thought, a product of evolution, Gaia cannot be an organism[4]. In the words of Richard Dawkins:

> *The Universe would have to be full of dead planets whose homeostatic regulation systems had failed, with, dotted around, a handful of successful, well-regulated planets, of which the Earth is one. Even this improbable scenario is not sufficient to lead to the evolution of planetary adaptations of the kind Lovelock proposes. In addition we would have to postulate some kind*

[4] Organisms and Darwinian and biological individuals are, for most philosophers of biology, not the same. This is an ongoing debate within biology, with some scholars calling for a synonymous use of organism and biological individuals. At the moment this paper is written, however, it is generally accepted that they are not the same (Pradeu, 2016). However, most critiques on the organism Gaia were based on the impossibility of it being a Darwinian individual. Even though they are not the same, these terms were used interchangeably in the debate surrounding the organism Gaia. As such, I will not discuss the differences between organisms and Darwinian individuals within this paper. Instead, I recommend Pradeu's article as an introduction to the debate.

of reproduction, whereby successful planets spawned copies of their life forms on new planets. (Dawkins, 1982, p. 236).

In recent Gaia Theory literature, this critique has been partially averted. Lenton & Wilkinson, for example, argue that regulatory feedback does not necessarily have to 'arise by Darwinian selection', as Kirchner argues. Regulation can also be seen as an emergent property, uninfluenced by selection processes. Lenton and Wilkinson name density dependent control of population as an example of this (Lenton & Wilkinson, 2003, p. 6). One of Lynn Margulis' main contributions to Gaia Theory was close to this: she argued that her autopoietic Gaia did not have to be a result of Darwinist natural selection (Ruse, 2015, p. 175). Ford Doolittle, another early critic from the evolutionary biologist camp, has argued that Gaia can be seen as a product of natural selection if we consider Gaia to be an clade but *not* a Darwinian individual. He defines Gaia as a *clade,* which is a population of individuals descended from the last universal common ancestral individual or LUCA. The possibility of Gaia as a clade, for Doolittle, allows Gaia to be theoretically possible. This does not mean that Gaia exists, but it might within this theory (Doolittle, 2019). This postulation avoids the two aforementioned critiques, as clades are compatible with Darwinist theory. This critique and counterarguments in all cases come down to how an *organism* is defined (Doolittle, 2017), and to what degree the organism aspect of Gaia Theory is taken seriously.

Ford Doolittle, before he started working on 'Darwinizing Gaia' and his view was like Dawkins', judged that believing Gaia Theory to be compatible with natural selection could potentially even be dangerous. This is because believing that the earth will 'select' itself could imply that it can also fix itself, which is obviously not guaranteed. Lovelock himself seems to be vague on this implication of a Darwinist Gaia – in some writings, he champions Gaia's self-restoring capabilities. In others, he argues that humanity and its activities on earth (which are part of Lovelock's Gaia) pose a fundamental danger to our earth (Doolittle, 1981). As discussed in the previous chapter, Lovelock often associated Gaia Theory with 'planetary health' too. The self-restoring implication, to Ford Doolittle, was a "BBC Theorem" fallacy, meaning that there is a pre-assumption that the world is harmonious. (Ruse, 2015, p. 30). Interestingly, Ford Doolittle now seems to have embraced Gaia Theory almost completely in terms of scientific validity, as he has spent a fair share of his recent work 'Darwinizing' Gaia in which he has tried to describe biochemical cycles as Darwinian units (or individuals). Now, according to Doolittle, the task lies in understanding to what degree Gaia Theory and its feedback systems are true through philosophical, computational and empirical experiments (Doolittle, 2019).

To the Neo-Darwinists' argument that Gaia cannot be alive because living organisms should be the direct result of natural selection, Lovelock responded:

> *is it true that Gaia is not alive like you or me. It has no sense of purpose, it cannot move by its own will, or make love. But then neither can many bacteria. Are these not alive? And what about grandmothers, they cannot reproduce; neither can Lombardy poplar trees, all of which are male. Or, on a larger scale, what about whole ecosystems, such as forests? Are all of these, which we thought were living, to be pronounced dead.* (Lovelock, 1991, pp. 29–31).

Thus, Lovelock's definition of what life is should be understood differently from what the evolutionary biologists argue as the nature of an organism or individual is (namely, being a result of natural selection). Lovelock instead favoured the definition of living matter which W.B. Cannon put forward: an entity being homeostatic, having internal balance. This opposes the natural entropy of the universe, and can therefore be seen as living instead of non-living matter. Dawkins, in response to this, argues that this homeostasis, for living beings, is a result of natural selection (Ruse, 2015, p. 150). Arguably, Lovelock just tried to fit 'being alive' in a definition that would support his ideas of the living organism Gaia. Simultaneously, he largely ignored any biological discussions surrounding the differences and similarities between organisms, biological and Darwinian individuals and other possible living forms.

In any manner, Lovelock and the Neo-Darwinists were having a discussion while using different definitions. Lovelock's metaphorical organism was never an organism in the sense that evolutionary organisms are, as emphasized by Lovelock: "*when I talk of a living planet, I am not thinking in an animistic way, of a planet with sentience, or of rocks that can move by their own volition and purpose. I think of anything the Earth may do, such as regulating the climate, as automatic, not through an act of will, and all of it within the strict bounds of science"* (Lovelock, 1991, p. 31). In an unpublished letter to Lovelock in 1997, Darwinist W. D. Hamilton addressed this friction between definitions:

> *You take a word, "organism", which has acquired an accepted meaning among Darwinists as a unit of system subject to natural selection, and you apply [it] to a system that can't possibly be subject to natural selection. Because there is only one of them! Obviously, that is equivalent to asking everyone to change their concept of an organism. This may be what you want, but you should not be surprised at resistance! I think you would get further in attracting interest if you were to invent a new term – well, I suppose "Gaia" is actually that- and explicitly deny that you are saying that the planet is an organism. Just calling it a "super" organism doesn't help here because that term is already in use by Darwinists for the objects like social insect colonies where natural selection is still in play.* (Ruse, 2015, pp. 163–164).

Many of these original critiques on the organism happened *before* Kirchner's versions of Gaia. After that, it became apparent that the organism metaphor was not meant literally in most Gaia discussions. Lovelock and Margulis have rejected Gaia as a literal 'superorganism' since the late eighties, which is when Kirchner put forth his versions. As a result, the friction between Lovelock and the evolutionary biologists disappeared to a degree. Nowadays, a fair share of Gaia's initial critics such as Doolittle and Hamilton at least partially accept Gaia Theory, and Gaia Theory itself has shifted towards definitions that better fit contemporary understandings of evolutionary biology (Lenton & Wilkinson, 2003). Critics such as Doolittle and Hamilton now consider Gaia Theory a useful framework to perform research through. However, not all of the evolutionary biologists have been convinced by Lovelock, as Darwinian critiques are ever as present in modern Gaia Theory discussions.

The philosopher Peter Godfrey-Smith, for example, argues that global homeostasis might exist, but he directly denies that such a homeostasis is a consequence of natural selection favouring said homeostasis. Godfrey-Smith's critique aligns with the earlier reductionist critiques that evolutionary biologists offer, and can be seen as a direct extension of fundamental Darwinist thought. Godfrey-Smith argues that we might indeed find Gaian processes, but says about those: "*The fact that the Earth is not like an organism doesn't make it impossible for some of those relationships to be present. If they arise, they arise as fortuitous byproducts of the evolution of particular living things."* (Godfrey-Smith, 2015, p. 19). Any systems-level function is denied or explained as results of interactions and reproduction of the species such a system consists of. Likewise, Richard Dawkins and several of his colleagues still reject Gaia Theory on the grounds of the aforementioned reasons.

1.2.2 Gaia Theory as pseudoscience

The scientific community initially criticized Gaia Theory for being pseudo-scientific. Initially, many scientists thought it realistically impossible to design a scientific test to verify Gaia Theory. In Popperian paradigms of science, a theory must be testable to be considered scientific. Thus, if a scientist adheres to the Popperian view of what science is, Gaia Theory could not be science, and would instead become metaphysical 'nonsense'. To recall Dawkins' comment on Gaia, the only real test to verify or discard Gaia would be to have a universe full of dead planets and a handful of successful, well-regulated planets. Even if that scenario would be realistic, which it is not, that would only partially validify Gaia Theory as a scientific Popperian theory. This is because there is still only the result of Gaia, and no possibility to test Gaia itself. Lovelock assumed that Gaia *emerged* together with the evolution of photosynthetic organisms. Therefore, to truly make Gaia valid within a Popperian framework, a test that simulates these conditions at planetary scale must be designed, which is virtually impossible (Deane-Drummond, 1996).

Of course, modern philosophy of science is not solely Popperian anymore. Philosophers of science have turned towards definitions and understandings of science which allow for broader approaches to validify scientific theories. Scholars working on Gaia Theory understood that Gaia could not be tested in the Popperian sense, so they instead urged the scientific community to see the idea of Gaia as a Kuhnian paradigm shift. Normal science, for Kuhn, does not concern itself with novelties of fact or theory and is successful when it finds none. A paradigm such as the Popperian paradigm searches for empirical data which is consistent with its assumptions. Therefore, what should be discussed is not whether the empirical data itself is consistent, but whether the assumptions which form the foundation for the empirical data are appropriate in the analysis of the study object (Fracchia & Lewontin, 2005, p. 17). Hereby, critiques on Gaia Theory such as Dawkins' dead planets become insufficient as an argument in favour or against scientific validity. Gaia, as an object of analysis, does not lend itself to Popperian verification on a planetary scale and therefore should not be treated as such. Instead, Kuhnian philosophers of science argued in favour of Gaia Theory as a scientific framework to perform research through. Lynn Margulis has even stated that she thought she and Lovelock were 'constructing a paradigm' (Ruse, 2015, p. 148). In a sense, this is true. Gaia Theory has opened up a field of research, from which many results have sprung of which some supported Gaia Theory and some did not. Within the Gaia 'paradigm', there are obviously a lot of testable, smaller hypotheses which follow from Gaia Theory. The interconnected feedback systems that Gaia investigates are important to map out, even if the Gaia Theory itself turns out to be false.

Still, even for scholars who adhere to Kuhnian philosophy of science argue that Gaia Theory can be scientifically problematic – there is a major part of Gaia Theory that cannot be tested in any way, especially in the more 'extreme' versions of Gaia. An example of this is the regulation towards 'optimal' states such as *Optimal Gaia* suggests. Given the tautological nature of this formulation, optimality is always tested in the frame of what is defined as optimal. This is what Kuhn speaks of when he calls science successful when it finds no novelties: the very tests are designed to acquire a certain result within the frame or an arbitrary 'optimality'. (Stead & Stead, 1994). This is what Kirchner hints at in his critiques on the *geophysical* and *optimizing* versions of Gaia – there is an inherent unscientific side to Gaia Theory when it becomes too radical in its formulations.

With regards to the aforementioned discussions on Darwinian individuality and Gaia Theory, Lovelock himself did not exactly help in making Gaia a scientifically relevant theory, as he frequently used terms and concepts which he was not well-acquainted with either. For example, Lovelock often associated Gaia with group selection, an evolutionary concept which was rejected by Dawkins and contemporary evolutionary biologists. Dawkins, being a heavy critic of both Gaia Theory and group selection, instantly criticized Lovelock on this by pointing out the flaws of Gaia in group selection. However, modern philosophers of biology argue that both Dawkins and Lovelock did not really understand what they were talking about with regards to Gaia and group selection. As Massimo Pigliucci states: "*group selection works just like kin, individual or gene-level selection: it requires populations of objects to compete with each other for recourses and to produce offspring that reliably resembles them. "Gaia" does not qualify, quite independently of whether group selection is a viable theoretical possibility in general (it is) and whether it actually occurs in nature."* (Pigliucci, 2014, p. 114). Therefore, to even discuss Gaia and to argue in favour of or against its compatibility with a concept such as group selection demonstrates a lack of understanding of Gaia Theory itself. Lovelock, who was not as much an established scientist as Dawkins was, made it hard for fellow scientists to accept his ideas regardless of the contents of Gaia Theory itself. By using established concepts such as the definitions of life and organisms wrongly, constructive debates within an academic sphere were hardly possible.

Lovelock's own attitude towards science as a method and a community did not help either, though. Statements made by Lovelock such as "*The progress of good science is slow and unpredictable and all too often awaits the appearance of a key thought in the mind of a genius"*(Lovelock, 1991, p. 15) illustrated his character. Lovelock identified himself as some sort of scientific sceptic, and saw himself as courageous to speak out on all that he saw wrong in science. He applauded himself on being an outsider. Paired with Lovelock's association with other scientific rebels, it is easy to understand how Gaia Theory came to be seen as pseudoscientific by association, regardless of the contents of Gaia Theory itself. Lovelock favourably reviewed Fritjof Capra (the author of *The Tao of Physics),* and Rupert Sheldrake (author of *New Science of Life: The Hypothesis of Morphic Resonance*), who had both been controversial scientists in their own right (Ruse, 2015, pp. 38–39). Lynn Margulis started portraying herself as a scientific iconoclast too, often purposefully striking scientific feathers. Since Margulis fervently championed holism and emergence, she often went as far as to deny Darwinism (Pigliucci, 2014, p. 120), which was and still is the commonly accepted theory behind evolution.

Neither did Lovelock's ignorance of the western intellectual and scientific traditions help. Lovelock was and is mostly an engineer. Despite having published academically throughout his life, Lovelock comes from a mechanistic engineering tradition, and has no real training in philosophy besides some theological knowledge which he acquired in his Christian upbringing. Lovelock was mostly unaware of many traditional discussions which his work bordered on. Examples of this are Lovelock defining 'life' in his own way (about which Hamilton wrote the unpublished letter in which the excerpt in chapter 1.2.1 can be found) and the teleological discussions over final causes which happened during the Scientific Revolutions. As Ruse states, "*He was a mechanist, but he didn't always talk like one. In his lack of sophistication about the ins and outs of final-cause thinking, he did not always even think like one. …. Remember that Lovelock is not a deep thinker, in the sense of conceiving of and developing fundamental theories of science. He is a tinkerer, an inventor, an instrument maker – and such people do think teleologically*." (Ruse, 2015, p. 187). The same argument can be made about Lovelock's thoughts on Gaia as an 'emergent' theory, in which emergence should oppose the traditional mechanistic understandings of our earth. As Ruse points out, Lovelock's notions of what emergent systems are rely on feedback loops – which are completely mechanistic. *Daisyworld* too can be seen in this light – to support the 'emergent' Gaia Theory, Lovelock proposes an ultra-mechanistic causal model, *Daisyworld* (Ruse, 2015). Lynn Margulis of course provided Gaia Theory with clearer holistic and emergent examples and research. However, a case such as Lovelock's merely shows how scientifically confused Gaia sometimes was.

One could also argue that calling Lovelock a holist or a reductionist both do not suffice. Instead, what Lovelock might better be characterized as is a holistic materialist. Holistic materialism proposes that even though reductionism is technically right (the whole is not more than the sum of its constituent parts), the study of these parts is not the correct way to approach research. They argue that the interaction between parts must be known to understand the parts themselves. It makes sense to group Lovelock under such a classification. Even if this classification might fit better however, I will refrain from using it in this paper. This paper deals with the historical development of Gaia Theory and throughout its history, the actors within this debate have been framed as either holists or reductionists. Further literature on the topics dealt with in this paper concerns itself with the holist/reductionist dichotomy, and does not introduce the further possibility of Lovelock being a holist materialist. Thus, I will follow the holist/reductionist dichotomy as to further build upon literature, and I suggest reframing Lovelock as a holistic materialist for further research.

1.2.3 Gaia Theory and 'wrong' teleology

Gaia Theory has historically been accused of being teleological. In order to understand why Gaia Theory is considered teleological, and why that can be problematic, it is necessary to understand the philosophical debates on the subject of teleology. Teleology is often seen as problematic in science, and was 'purged' from the sciences which considered themselves as fundamental, such as mathematics and physics (Walsh, 2008). This sentiment has, at least historically, spread to biology too. Teleology arguably deserves a place in biology however, as will be briefly outlined below before teleological critiques on Gaia Theory are introduced.

The original meaning of teleology comes from its namesake *telos,* which Aristotle used to describe what he considered the goal-driven behaviour of living beings. Aristotle's teleology is deeply naturalistic and functional – the goal or end-state of an organism is for Aristotle an inherent property of the organism. Therefore, in Aristotelean teleology, we can speak of teleology when parts have a function which works towards an end-state. This teleological understanding of organisms was later rejected in the Scientific Revolution, when Descartes argued that organisms which are not human are *bête machines* (Walsh, 2008, p. 114). The Scientific Revolution and its reductionistic worldview still have its influence today, and teleology in biology would not really get 'revived' until Kant discussed the topic in the late 18th century. Kant argued that organisms are natural entities and therefore indeed subject to mechanical explanation. However, organisms are also self-organizing entities, in which the goal of the organism inherently defines the properties of its parts. Therefore, Kant argues, organisms are both causes and effects of their parts. Here, mechanical explanations explain how organisms work as effects of their respective parts, whereas teleological explanations account for the organization and regulation of their parts. This, for Kant, is enough to justify an immanent teleology, even if the teleology itself is not 'physically' there (Walsh, 2008, p. 115).

Teleology in biology took yet another turn in the wake of Charles Darwin's natural selection. Initially, biologists thought that Darwinism had finally declared teleology 'dead'. However, the relation between Darwinism and teleology is somewhat more complex than that. Darwinism does indeed refute any deistic or vitalistic teleology but *revives* naturalistic teleology. From Darwinism, *selection explanations* can be constructed. Selection explanations are explanations in which the consequence of a trait accounts for why that trait is possessed and accounts for its differential perpetuation and maintenance in populations (Lennox, 2019). Thus, teleology in biology can be understood in many different ways. In modern evolutionary theory, teleology is generally separated in teleological functions regarding parts (organs) in organisms, and the teleology of organisms and their agency. These different uses of teleology often make discussions concerning Gaia Theory confusing, as scholars are talking with different terms. Double this with the fact that Lovelock was likely not aware of this tradition, yet still spoke of teleology and Gaia Theory.

Within different interpretations of Gaia Theory, it must be understood that a large share of the criticisms in this field attack the *Geophysical Gaia* or the *Optimizing Gaia.* These sentient-seeming forms of teleology are forms of Gaia which Lovelock always denied. In the preface of the first public book Lovelock wrote on Gaia Theory, he warned:

> *Occasionally it is difficult, without excessive circumlocution, to avoid talking of Gaia as if she were known to be sentient. This is meant no more seriously than is the appellation 'she' when given to a ship by those who sail in her, as a recognition that even pieces of wood and metal when specifically designed and assembled may achieve a composite identity with its own characteristic signature, as distinct as being the mere sum of its parts.* (Lovelock, 1979, p. x).

Any intentional steering towards optimal states within Gaia was, for Lovelock, a misunderstanding as the idea of Gaia being sentient was nothing but a literary description.

Even though Lovelock denied this, 'sentient' teleology is often implied in his Gaia writings. Lovelock's prose and his choice for *Gaia* as the name of his concept all evoke deity-like associations, implying that Gaia is a steering, sentient creature. Lovelock himself even argued that the fact that Gaia Theory was often interpreted as a sort of neo-Paganism was an unintended result of this association with mythology (Ruse, 2015). This creates an awkward tension in Lovelocks' writing. Even though Lovelock's aforementioned preface can be read as a definitive denial of the sentient organism Gaia, scientists have often interpreted Gaia otherwise. For some this might have been an incidental misinterpretation, given Lovelock's confusing prose outside of that preface. Others might have wilfully searched for vague prose to further undermine the Gaia they were not fond of.

Massimo Pigliucci for example, a well-known name in philosophy of biology, critiques Gaia for 'being an organism'. He does this by citing Ruse's book Michael Ruse's *Science on a Pagan Planet,* instead of returning to the source material. The point Piggliuci tries to make (that the earth being a literal organism is a preposterous claim) would be fair, if Lovelock and Margulis had intended it that way. Instead, what Piggliuci is doing looks more like cherry-picking to oppose a theory he deems pseudo-scientific (Pigliucci, 2014). Another example of this is Toby Tyrell's book *On Gaia: A Critical Investigation of the Relationship between Life and Earth.* Tyrell also argues that Gaia is a 'higher' system, in which some sentient being steers the conditions of the earth (Tyrell, 2013). Again, such a criticism would be fair if that is what Lovelock had intended to communicate. Even though Lovelock was not consistent in his formulations of Gaia Theory, such black-and-white critiques on the 'teleology' of Gaia Theory are quite obviously a case of cherry-picking.

Besides the accusations of Gaia Theory being teleological and sentient, Gaia Theory has also been criticized for its metaphorical nature. This idea is closely related to the teleology that is associated with Gaia Theory. Stephan Jay Gould, for example, has argued that Gaia is a *metaphor* instead of a *mechanism*. Without mechanisms driving Gaia Theory, Gould argued, self-regulation could not be proved and could therefore not be scientific. This is, as discussed in chapter 1.2.2, not an unfair criticism. Lovelock was rightfully criticized for his lack of mechanism, to which he responded by developing *Daisyworld.* In reaction to Stephan Jay Gould's metaphor critique, philosophers of metaphor have argued that 'mechanism' itself is also a metaphor. An entity being a metaphor does not inherently exclude it from being a mechanism, and therefore one cannot scientifically disqualify Gaia solely on the grounds of it being a metaphor and not a mechanism (Abram, 1991).

A similar critique and reaction can be found in Richard Dawkins' response to Gaia Theory. Besides Dawkins' critique on Gaia Theory in relation to Darwinian individualism, Dawkins argued that Gaia is the 'sentient organism' discussed earlier in this chapter. The critiques from Dawkins and contemporaries can now, in hindsight, be contextualized in the aforementioned reductionistic academic atmosphere (Ruse, 2015). In the time in which Dawkins and his colleagues formulated their critiques, biology moved towards the idea of individual genes fighting for survival, nowadays popularised as "*The Selfish Gene*". Like the aforementioned mechanism-metaphor, a gene being selfish is also a metaphor which implies agency in an entity which is not sentient. However, Lovelock took the criticisms seriously. Even though the criticisms were also incoherent in how they understood metaphor, Lovelock understood that Gaia Theory needed mechanisms to be accepted in the scientific discourse. As biological critic Paul Ehrlich stated: "*That is why in the context of Gaia, I find myself taking a reductionistic position; the idea that life evolves in a way to make the planet more hospitable for itself collapses for want of a mechanism"* (Ruse, 2015, p. 152). Thus Lovelock set out to create a model that showed a mechanism through which Gaia could happen, without being illicitly teleological. To return to the Aristotelean idea of teleology, the only teleological explanation of Gaia that could exist was a final cause connected to natural selection. Out of this need for a mechanism, *Daisyworld* was created.

Daisyworld proposed a mechanism which supported the teleological final cause as a result of natural selection. Here, the units of natural selection are the individual daisies. *Daisyworld* showed life on a planet reaching an equilibrium that conformed with Darwinist ideas. *Daisyworld* of course is a model, and real empirical evidence was and still is needed on planet Earth. However, *Daisyworld* brought the Darwinists and Lovelock closer together (Deane-Drummond, 1996; Ruse, 2015). From the development of *Daisyworld* and onwards, Lovelock no longer spoke as much in metaphorical and teleological terms, but instead moved towards the language of biologists and ecologists (Rushton, 2008).

1.3 The organism metaphor and criticisms of Gaia Theory

All of the criticisms discussed here are related to the organism metaphor. The Darwinist-individuality criticism concerns itself with the use of the organism concept for Gaia Theory. Whereas Lovelock uses 'organism' as a metaphor, a means to get his ideas across, the Darwinists could not permit him to use a strictly defined term that freely. Even though Lovelock tried to fit Gaia within the Darwinist critiques, as shown before, the friction could partially be traced back to this loose use of the word 'organism' on Lovelock's side.

Similarly, the pseudoscience and teleology critiques can be related to the organism metaphor too. Gaia Theory was partially regarded as pseudoscientific as it initially provided little explanatory value and instead chose to speculate. Lovelock was more interested in the idea of the earth as an organism (even if meant metaphorically) and he never shied away from using this metaphor to promote Gaia Theory as a scientific theory to the grand public. Part of the reason that Gaia Theory was problematically seen as teleological was because the organism metaphor conjured associations of agency, instead of the functions-of-parts teleology that Gaia Theory argued for. When agency is implied, it is not a far stretch to think of Gaia as a sentient being.

Since the aspect of Gaia being a metaphorical organism seems to be so crucial in understanding the theory and the criticisms it has attracted, the organism metaphor itself needs to be discussed.t The next chapter will dive deeper into philosophy of metaphor and the organism Gaia as metaphor. It will show what role the organism metaphor has played in the development of Gaia Theory.

2. The organism metaphor and its role in Gaia Theory's development

Gaia Theory heavily emphasises the metaphor of the earth being a living organism called *Gaia.* As I have shown in the previous sections, Lovelock (while maintaining the organism metaphor) has always argued that Gaia is scientific, and has, after critiques from Dawkins, Doolittle, and the Gaia Conferences, attempted to redefine Gaia Theory towards a theory that fits better with other contemporary scientific knowledge. At the same time, a significant share of the criticism directed towards Gaia Theory is concerned with the actual metaphor. This metaphor-directed criticism has had a significant impact on the scientific reception of Gaia Theory too, and has contributed to its public popularity.

In this chapter, I introduce a philosophy of metaphor and its relation to scientific validity and public reception. What does philosophical literature say about these subjects? What is the role of metaphor? Are criticisms aimed at the metaphorical nature of Gaia Theory valid? Is the mismatch between evolutionary scientists and Lovelock and Margulis not merely a result of metaphors being taken too literally?

In this chapter and throughout the entire paper, the metaphor of Gaia as an *organism called Gaia* is investigated. The metaphorical aspects of Gaia are not limited to the organism, as Gaia for example carries mythological associations with it as well. For the sake of narrowing the research scope, however, this paper limits itself to the organism metaphor, with brief sidesteps to other associations if need be.

2.2 Philosophy of metaphors

The use of metaphors in science, science communication and philosophy of science has been and still is a point of research and discussion. Science aims to describe the world as it is. Therefore, metaphors appear to be the nemesis of scientific description – if something can be described as it is, why would science wish to describe it otherwise (Bradie, 1999, p. 159)? Therefore, scientists and philosophers of science have often called for a metaphor-free science, in which everything is described as a mathematical model. This is of course not a new idea but instead one that has persisted for centuries: "*The idea that mathematical models can, in principle, provide metaphor-free knowledge of the world is just a manifestation of another meta-model from the scientific revolution – one we might attribute to Galileo Galilei who famously suggested that the book of nature is written in the language of mathematics."* (Bradie, 1999, p. 163). One could argue that the logical positivists of the Vienna circle tried this too in their attempts to create a formal philosophical language. This view of reality can be criticized. Mathematical models of empirical phenomena are constituted of "metaphorical redescriptions" of said phenomena, which will be discussed further later in this chapter. If this is the case, then even science described as pure mathematics will not and cannot be free of metaphor (Bradie, 1999, p. 165).

Especially in the fields of biology and ecology, metaphors invade the language of science. Often, scientists are not even aware of the metaphor-laden language they use. This has implications for the way science is communicated and understood (Taylor & Dewsbury, 2018). For example, philosophers of metaphor have argued that many metaphors used by biologists and ecologists are rooted in competitive, militaristic and technology-related language. This reinforces ideas on how organisms interact, as it implies that there is inherent aggression between organisms and symbiotic processes are overlooked. This is not necessarily problematic in itself, but it can be when the idea of competitive organisms is transposed to, for example, human societies and politics. Therefore, metaphors are not isolated compartments of language, devoid of any implications – the choice for a specific metaphor has its implications. It influences how we visualize concepts, and how we cognitively use these concepts with regards to other concepts. Hereby, metaphors become messengers of socio-political norms and values. Awareness of the potential of metaphors to carry social-political messages transforms them into a tool to change or restructure societal ideas. (Taylor & Dewsbury, 2018). This, in itself, validates research into metaphors in science, as they are no longer merely literary devices.

A few examples of metaphors in biology and ecology reinforcing certain social or political norms are (a) entomologists' slavery metaphors to describe ant colonies. By using anthropomorphic slavery language, which has also been used and still are used to describe human slavery, certain human systems can be partiality legitimized. If slavery can be found in the animal kingdom, is it not inherent to living societies? (b) the 'war on invasive species'. Regardless of the ecological science which indeed suggests that invasive species can at times be harmful to ecosystems, the metaphor choice of 'war on invasive species' is fear-inducing. It implies that invasive species are inherently something to worry about, and is arguably rooted in the values of and concerns of farmers and economic stakeholders.

Recent scholarly debate on metaphors have even implied that our very own human cognition is metaphorical in nature. Lakoff and Johnson have developed a theory of conceptual metaphor, which posits that knowledge is an emerging result of social and embodied physical experiences. An implication of this view is that metaphors are no longer merely linguistic embellishments, but the foundations for conceptual understandings that map meaning from one domain of knowledge to another. Embodied experiences are used as cognitive representatives in understanding abstract phenomena (Lakoff & Johnson, 1980). This is especially relevant when dealing with macrocosmic (e.g. the universe, time, and indeed, earth) and microcosmic (e.g. cells, protein receptors) phenomena, which are translated to mesocosmic experiences. This is accurately explained in the following quote:

> *Consider the following constructs where scientists make use of everyday experience to explain their theories. Robert Hooke was the first to denote the cell using the term "cell" when an image of a piece of cork under his microscope reminded him of the small rooms, or cells, occupied by monks in monasteries. Kepler developed his concept of planetary motion by comparison with a clock. Huygens used water waves to theorize that light is wavelike. Arrhenius described the greenhouse effect by referring to his experience with hot pots. In ever new variations, scientists employ experiences from everyday life to understand scientific phenomena.* (Niebert & Gropengießer, 2015, p. 5).

From the previous few paragraphs, it should be clear that metaphors are inherent to science, and not something that can be done away with easily. Especially in ecological and biological sciences, choices for metaphors have far-reaching implications. Therefore, debates on the nature and the application of metaphors are necessary. The next subchapter introduces stricter definitions of metaphor and maps out the contemporary philosophical understanding of metaphors. It will specifically focus on Bradie's work on the functions of metaphors and Kampourakis' structure of metaphors. These will form the basis through which the Gaia metaphor will be investigated in this paper.

What is a metaphor?

What a metaphor exactly is is something that has been the subject of continuous scholarly debate. To start the discussion in this paper, I will first introduce some definitions before moving on to a more thorough inquiry. Taylor & Dewsbury define a metaphor as: "*A comparison between two seemingly dissimilar concepts that involves the "Carrying over a word from its normal use to a new use"* (2018, p. 1).

Lakoff & Johnson offer a simpler definition: "*a metaphor is understanding and experiencing something in terms of something else"* (1980, p. 35). Through the definition Lakoff & Johnson suggest, a metaphor is no longer merely linguistic. Now, metaphorization is also the interaction of the 'source', being human experience, with the structure of the 'target', being knowledge. Therefore, a metaphor is based on the interaction of an individual and the world (Kassymova, 2020).

In the past, the main philosophical view of what metaphors are and how they work were described as the *substitution view of metaphor.* In this view, the metaphorical expression M was seen as a substitute for L, being the literal expression. With the *substitution view,* a metaphorical expression is always seen as an alternative for L which could have been said literally. Hereby, M becomes rhetorical, and has no philosophical value. Philosophers therefore argued that metaphors had no place in philosophy, as they only distract from the essence. Metaphors supposedly were only semantics. Not quite satisfied with this, philosopher Max Black has proposed an alternative view of metaphors, which he calls the *interaction view of metaphor.* Black argues that meaning is created through the interaction between the metaphor and the source. In his own words: "*When we use a metaphor we have two thoughts of different things active together and supported by a single word, or phrase, whose meaning is a resultant of their interaction."* (Black, 1955, p. 285). The understanding that is created by imposing the frame of the metaphor upon the source is not the same as the meaning of the source. Black argued that a metaphor has a *focus* and a *frame.* The *focus* expresses the metaphorical idea, whereas the sentence in which that expression occurs is the *frame.* The *focus* without the *frame* would be the literal meaning of the metaphor – only through the *frame* does the metaphor gain its metaphorical meaning. Black gives us the example "man is a wolf", in which man is the focus, and the wolf is the frame. An important note here is that aspects which are associated with wolves differ per culture. Therefore, meanings and understandings of metaphors are culturally dependent and flexible. This disproves the *substitution view,* as the meaning of the focus cannot remain unaffected by the metaphor (Kampourakis, 2016).

Through the interaction view, the main importance of metaphors becomes clear: metaphors emphasize certain aspects of the source, and neglect others. Kampourakis extends this *interaction view* into what he calls the *structure-of-metaphor* scheme, and summarizes the components of this scheme (Kampourakis, 2016, p. 108):

1) A principle subject P

2) A secondary subject S

3) A set of implications which are associated with S

4) A set of attributions which P acquires by associating P with S

5) A set of properties of P which are hidden by associating P with S

This interaction view of metaphors arguably shows that all explanations (including mathematical explanations) are metaphorical redescriptions. When theories are applied to reality, the theoretical model is the subject S, which illuminates the principal subject or empirical phenomena P. The structure of S brings implications with it, as seen in the scheme above. Therefore, the application of theory in reality makes the phenomena acquire the structure of S, and therefore its implications. As Bradie says it:

> *The bottom line is that theories "connect up" with the world via metaphors. Each time a theoretical model gets applied, a metaphor is involved. When the application is new, we are struck by it; when it becomes commonplace, we often fail to note the use of metaphor. …. Information becomes data only insofar as an investigator "sees" it as significant. It becomes significant because of attributes that are induced by the implicational structure of a theoretical model.* (1998, p. 130)

Bradie identifies three functions of metaphors in science. These functions are not mutually exclusive as a metaphor can easily have a combination or all three of these functions. Bradie has identified these functions, and Kampourakis gives examples of Bradie's functions with regards to the protein-receptor metaphor, as shown below: (Bradie, 1999, p. 161; Kampourakis, 2016, p. 108):

1. The *Heuristic* function: metaphors under this category are useful in exploring new phenomena in reference to already understood phenomena. Kampourakis' example: thinking of a membrane protein as a receptor enables scientists to explore its function.
2. The *Theoretical* function: theoretical metaphors are useful to help understand explanations and theory. These are often indispensable for science, as theoretical metaphors make comprehensible that which is too abstract or too complex for the human brain. Kampourakis' example: after scientist realized the membrane protein functioned like a receptor, it could henceforth be described as a receptor-protein.
3. The *Rhetorical* function: rhetorical metaphors help in communicating scientific ideas to non-experts. Scientific concepts are, in rhetorical metaphors, transposed to something the non-expert is more familiar with. Kampourakis' example: the protein can be understood as a receptor in reference to other receptors to make the layman understand the role of proteins.

A few problems arise with the use of metaphors in science, though. Obviously, there is a risk of confusing the target domain and the source domain. This is an aspect Dawkins' *selfish gene* has been criticized for. The gene itself is never selfish in the sense that we understand selfish – a gene does not make conscious choices in favour of its own survival. There are no intentions in genes. The selfish gene helps us understand how genes affect life, but the selfishness is in every sense metaphorical. Another example of this is the idea that proteins can act as 'signals' or 'receptors', which suggests that proteins possess agency (Kampourakis, 2016). Another less obvious risk is that certain aspects of the source domain get overlooked or overshadowed because the metaphor only covers a certain aspect of the source domain. Put more simply, the metaphor does not quite fit for its purpose (Kampourakis, 2016). This is of course a problem that logically follows from the *structure-of-metaphor* (henceforth abbreviated as SoM) scheme and can be seen in a lot of popular metaphors, as will be shown in the case study below.

'Natural selection' – a case study on metaphors and scientific development

To discuss how a metaphor plays a role in the development of a scientific theory, David Depew has used the case study of Darwinian natural selection. Depew outlines how the choice for the metaphor 'natural selection' has influenced the theory's discourse. Kampourakis, in another paper, describes the 'natural selection' metaphor in a SoM-scheme, and discusses what role the metaphor plays based on Bradie's metaphor functions.

Initially, Darwin used the term *natural selection* for the evolutionary processes he was describing. Darwin was criticized for this term – John Stuart Mill, for example, thought that natural selection took the role of an intelligent designer, thus becoming creationism without a creator. John Herschel was even harsher. Calling *Origin of Species* a book about the 'law of higgledy-piggledy', Herschel implied that natural selection offered an explanation that relied on 'a mixed bag of non-computable traits', instead of the computable factors that e.g. Newtonian physics were. Given these and other critiques, Darwin's' contemporary biologists Wallace, Spencer and Huxley urged Darwin to replace 'natural selection' with 'survival of the fittest'. Begrudgingly, Darwin complied. This shift in metaphor (from the 'creationist' natural selection to the 'scientific' survival of the fittest) opened up paths for Darwin's colleagues. Spencer, who actually coined 'survival of the fittest', used the new metaphor in favour of his own theory of evolution. In Spencer's *Principles of Biology,* he used natural selection to explain embryo development. Spencer's use of the theory was incompatible with Darwin's gradualism and changed natural selection into selection against the unfit. Of course, selection of the unfit sounds a lot more like survival of the fittest than natural selection does. This little history shows how a change in metaphor use can lead to the legitimization or the dismissal of certain theoretical aspects. This, of course, heavily impacts further developments of theory. Therefore, it is essential to identify metaphors, their uses and their theoretical implications (Depew, 2016).

Kampourakis used this exact metaphor problem of natural selection as well to demonstrate his *structure-of-metaphor* scheme, as outlined below (Kampourakis, 2016, p. 116):

> "P: differential survival in nature
>
> S: artificial selection by breeders
>
> I: this metaphor emphasizes that: some features are selected whereas others are not; the selected features serve some purpose; the apparent design in organisms is the outcome of such a selection process; features that do not serve a purpose may not be selected;
>
> A: this metaphor allows for the inferences that selection: can be a purposeful process; can be a conscious process; can involve an external selector who guides it; can result in intelligent design;
>
> Z: this metaphor masks the ideas that: natural selection is an unconscious process taking place in nature; the apparent design that we see in organisms is incidental; the purposiveness of features is internal (self-serving) and not external (other-serving)."

While Kampourakis argues that natural selection as a metaphor has great heuristic value, the theoretical value of it is limited. Selection intuitively feels like an active and conscious process, which natural selection is not. This association worsened with the introduction of "survival of the fittest", as shown before. Kampourakis argues that the natural selection metaphor also has complicated the theory's rhetorical power. Darwin used the metaphor of natural selection to make the complex process of evolution comprehensible, yet it did not really convince the public at large about the role it played in evolution. Until the 20th century, natural selection was not considered an important process in evolution. Only after genetic studies started to be done as a research field did natural selection become as critical to fundamental biological theory as it is today.

This case study highlights the importance of metaphor in the development of a theory. It is a case study in which the metaphor of natural selection helps us understand what natural selection is not, namely some process which is steered or directed towards an optimal state, even though the name implies as much. As a result of understanding what natural selection *is not,* we understand better what it is too. This paves the way for new metaphors which fit 'better'[5], even though new metaphors will obviously also have value and limitations (Kampourakis, 2016).

2.3 Philosophy of metaphors and Gaia

As seen in the last subchapter, metaphors are everywhere in science – a metaphor-free science is likely impossible. Therefore, the discussion about whether the organism Gaia is a metaphor and is therefore scientific or not becomes void. Rather, the question becomes how and whether the Gaia metaphor *suffices*. What does it add to our knowledge of our earth and our environment? What does it mask? Does the metaphor itself contribute anything to the idea that Gaia Theory tries to convey?

In this subchapter, I aim to sketch a narrative of how the organism metaphor has played a role in the development of Gaia Theory. As a starting point, I choose the first major Gaia book (*Gaia: A New Look at Life on Earth, 1979),* from which I move forwards in time. The philosophical background on metaphors, as outlined in the previous subchapter, will be interwoven throughout this narrative. The organism metaphor is put in contrast with machine metaphors, which arguably can be understood as reductionistic language. Moreover, I argue that Lovelock's and Margulis' academic 'split' was not only a result of their disagreement on the organism metaphor, but was a result of a far more fundamental theoretical disagreement between the two. Then, I introduce the ideas of some contemporary scholars who study Gaia and attempt to position themselves outside of the traditional reductionist/holist debate, and who use Gaia Theory and the metaphor to substantiate this idea. After this historical analysis of the metaphor, the *structure-of-metaphor* scheme is reintroduced and applied to this specific case study, from which I will show that the organism metaphor itself is to blame for many controversies surrounding Gaia Theory.

Metaphors in Lovelock and Margulis

As Gaia Theory developed, so did its use of metaphors. One primary source is sufficiently informative for an inquiry such as this one: the new edition of Lovelock's first major book on Gaia, which he named *Gaia: A New Look at Life on Earth.* In the new preface of *A New Look,* Lovelock addresses metaphors in his work, and how he felt that the use of the organism metaphor had changed over time. He discusses this with regards to the scientific development and public reception of the theory, and the choices he had to make in order to describe the Gaia he had in mind. Therefore, this preface acts as a frame to understand Lovelock's scientific intentions in, and therefore acts as an outline for the aforementioned narrative.

There is one general conclusion which can be discerned from this preface, which is a development that has become apparent already in the earlier discussed history of Gaia Theory: to have Gaia be taken seriously as a scientific theory, Lovelock had to tone down on the metaphorical language. "*The Gaia hypothesis was a vague speculation before the blood was drawn to leave the leaner and more*

[5] The essence of what a 'good' or a 'bad' metaphor in science is is not the scope of this paper, yet it is important in the academic relevance of this paper. Therefore, the conclusion of this paper contains a very brief discussion on what a good or bad environmental metaphor in science would look like, and whether Gaia does or does not hit the mark.

scientifically acceptable Gaia Theory. For this I am grateful to the critics." (Lovelock, 1979, p. xv), states Lovelock. He addresses having needed to adjust his metaphor:

> *This local and partial acceptance of the real science of Gaia, after twenty-six years in the wilderness, was not without conditions. Important among them is the demand that the new science of Gaia, Geophysiology, must be purged of all reference to mystical notions of Gaia the Earth Mother. Even metaphorical phrases such as 'Gaia likes it cool' to express the observation that the Earth system appears to flourish in glacial times must be cast out. …. Science is almost certainly needed to keep our civilization alive, and if Gaia is a good model of the Earth, then I must express it in scientific language.* (1979, p. xiv).

Still, it is apparent that Lovelock could never quite release the metaphors he was so keen of , and in a way begrudged the scientific path Gaia was forced to take too. Lovelock draws a distinction between his first book *Gaia: A New Look at Life on Earth* and his second book *The Ages of Gaia. The Ages of Gaia* was 'sanitized' by Lovelock, as to submit to scientific discipline:

> *As a scientist, I submit wholly to scientific discipline and this is why I sanitized my second book (*The Ages of Gaia) *and hopefully made it acceptable to scientists. As a man I also live in the gentler world of natural history, where ideas are expressed poetically and so that anyone can understand and that is why this book (*Gaia: A New Look at Life on Earth) *remains almost unchanged.*(1979, p. xiv)

And even though Lovelock 'set free' his metaphorical Gaia and let it become 'acceptable' to scientists, he very often still hints at his 'old' Gaia: "*The community of environmentalists include many who claim an ownership of Gaian ideas and they have a case. Jonathan Porritt put it well: Gaia is too important as a focus for Green thought and action to be conscripted by science."* (Lovelock, 1979, p. xiii). This is of course a common thread throughout Lovelock's work on Gaia. On te one hand, he tries to make Gaia a serious scientific theory. On the other hand, he rebels against that very science. This can also be observed in Lovelock's statements on his critics. For example, Lovelock acknowledges and simultaneously heckles Dawkins' critique on the metaphorical organism Gaia: "*If you are someone wanting to know for the first time about the idea of Gaia, it is the story of a planet that is alive in the same way that a gene is selfish."* (Lovelock, 1979, p. iix).

This leads the narrative to its first major conclusion: the backlash against Gaia can be understood as a clash between metaphors and their relative worldviews: Lovelock wanted to describe the earth as a poetic organism, whereas his contemporaries favoured a 'drier' science The poetic organism metaphor was intended to provoke a certain feeling attached to Lovelock's scientific ideas, which slowed the scientific acceptance of the theory. The next subchapter will outline how the clash between Lovelock and the evolutionary biologists should be understood as a clash between the organism metaphor and the machine metaphor.

Organisms, machines and Gaia

The difference in worldviews, and Gaia's relevance as a metaphor, mainly comes down to the metaphor's association with the organism. Lovelock himself of course denied that the organism aspect was of scientific importance, and only toned down on the metaphorical language because the critics called for it. The associations which come with the organism Gaia however lives on in scientific discourse with all its associated implications. As we will see later, Lovelock might have intended it that way too. As outlined in the chapters *History of Gaia* and *Critiques on Gaia,* the evolutionary biologists, spearheaded by Richard Dawkins, saw many problems in Gaia. The evolutionary biologists firmly placed themselves within the tradition of reductionist science – biology was studied as functioning parts in organisms.

In reductionist science, there is an unspoken bias that our world works like machines do, as first proposed by René Descartes (Kampourakis, 2016, p. 110)[6]. This worldview has consequences for the way we see the world. The first direct consequence of this machine-metaphor is that not only the whole world works like a machine, but individual, organismal parts become mechanical contrivances too. This leads to the conclusion that organisms themselves become machines. The modern Darwinian explanation of natural teleology is based on this worldview too: mechanisms that function towards an end, and have arisen as a result of natural selection, are the only acceptable teleological explanations for modern evolutionary biologists and adaptationists (Kampourakis, 2016). An example of a metaphor which follows from this machine-organism metaphor is the DNA-'blueprint', which supposes DNA is like a machine's blueprint: follow the instructions, and the machine is created.

There are certainly similarities between machines and organisms. Both are physical systems, are structured, use energy to work and have interacting parts. On the other hand, there are massive differences between machines and organisms too. For example, organisms have intrinsic purpose, whereas the purpose of machines is inherently external as they are created by a maker. Likewise, maintenance and repair of organisms happen in the system itself, whereas machines are generally repaired by the maker (Nicholson, 2013). The organism-as-a-machine metaphor banishes vitalistic or unnatural metaphysical ideas, which is not necessarily a bad thing. At the same time, it suggests intelligent design in nature. Even though this association sounds like a misinterpretation which can easily be avoided, it shows up in many different forms in the works of modern Darwinists. Richard Dawkins, for example, describes natural selection as "*the Blind Watchmaker",* which obviously plays with the idea of an external agent.

Richard Lewontin summarizes the problematic side of the machine-metaphor as such:

> "*While we cannot dispense with metaphors in thinking about nature, there is a great risk of confusing the metaphor with the thing of real interest. We cease to see the world as if it were like a machine and take it to be a machine. The result is that the properties we ascribe to our object of interest and the questions we ask about it reinforce the original metaphorical image and we miss the aspects of the systems that do not fit the metaphorical approximation.*(2000, p. 4)*"*.

In the "natural selection" case study by Depew, it became apparent that Darwin and the Neo-Darwinists who followed him never fully rejected the metaphor of the organism as the machine. To be more precise, the machine model became so prevalent it is no longer really noticed anymore: "*The ur-metaphor of all modern science, the machine model that we owe to Descartes, has ceased to be a metaphor and has become unquestioned reality: Organisms are no longer like machines, they are machines."* (Lewontin, 1996, p. 1).

Gaia, of course, suggests exactly the opposite of this: by being an organism and not a machine, the world is understood differently. Suddenly, philosophical understanding of the earth gains a new

[6] This statement arguably does modern reductionist science a bit short – many modern reductionists philosophers do not consider themselves machinists and vice versa. Still, this idea of a machine-like world is quite prevalent in modern science, and a fair share of scientific language can be seen as a result of this machine worldview.

dimension. By being an organism instead of a machine, the purpose of the world shifts from *external* purposiveness to *intrinsic* purposiveness. As the *telos* of the organism or the world is now internal, its only purpose is maintaining its own organization. Given this machine/organism distinction, it becomes clear why Gaia critics were so appalled by Gaia's telos: even if Lovelock denied teleology, calling Gaia an organism was inherently teleological in the traditional biological understanding. (Nicholson, 2013).

An organism also has a *transitional structural identity,* unlike a machine. This means that the organization of an organism remains even though the materials change, whereas a machine generally consists of the same components unless externally replaced. This is called the *metabolism* of an organism, and is not something that naturally occurs in a machine (Nicholson, 2013). Another aspect in which the organism Gaia leads to a shift in perspective is that of *functions of parts* in organisms. In an organism, the ascription of functions to the organisms' parts are based on how these parts help meet its physiological needs and cope in its environment. This has implications for the relation between *parts* and the *whole.* Parts are causally independent in a machine, they retain their properties regardless of their integration in the machine. On the contrary, parts in an organism are not causally independent but exist in a collective interdependence. Every part is needed for the generation and operation of other parts. In an organism, autonomy as a whole is maintained by the regulation, repair and regeneration of its parts (Nicholson, 2013). This difference between machines and organisms forms the foundation for the reductionist/holist distinction, which lies at the very core of the Gaia discussion and to which I will return shortly.

When talking about organisms and machines and their relation to Gaia, one obviously needs to remember that the organism Gaia is a metaphor. Thus, when we speak of the world as an organism or a machine and posit statements about parts and functions, we should always be aware of the fact that we are speaking in metaphors. As discussed earlier, an effect of frequent use of a metaphor is that at some point one no longer realizes they are using a metaphor. Metaphors do however carry philosophical implications, which carry over to the way the world and environment are understood. The aforementioned purposiveness or *telos* that arises with the organism metaphor, for example, only really happens when the world is literally seen as an organism, which is not quite wat Lovelock meant. With the use of the organism as a metaphor instead of as a literal explanation, the purpose is only an association of the metaphor. Of course, cherry-picking certain parts of what an organism is when using a metaphor is bound to lead to confusion – other people are not inherently aware of the exact aspects of the metaphor you are using, therefore it needs to be specified clearly or not used at all. Especially in a debate where teleology or purposiveness is so crucial, one should not ill-define what they are trying to say (Nicholson even argues that the essential difference between machines and organisms is the internal vs. external purposiveness, and that most other differences stem from that (Nicholson, 2013)).

This is of course where Lovelock historically made a mistake. By not integrating himself with long-standing biological discussions and just assuming definitions for concepts such as 'the organism' and 'life', Lovelock inherently pushed Gaia towards becoming a controversial theory in the biological community. This, as shown in chapter 1.2.1, leads to Lovelock further defining Gaia after he realised that much of the criticism he received were a fair attack on his ignorance of scientific traditions. An intuitive metaphor did not suffice to make Gaia Theory scientific – Lovelock needed to develop mechanisms that supported his theory. Thus, Lovelock created *Daisyworld*. This is an example of the structure of a scientific development Kampourakis outlined: as a result of Lovelock having to define what Gaia was not (an organism with inherent purpose), the scientific debate came closer to what Gaia actually was (a scientific idea on feedback systems which shared similarities with the way organisms work).

To contextualize the organism metaphor and its reception, the authority of machine metaphor within modern science must be understood too. The *heuristic* power of the machine metaphor is undeniably strong. The metaphor has been the champion of modern biology as its perspective has led to many new discoveries, which arguably follow from its reductionistic stance. Nicholson states this as such (and abbreviates the machine metaphor as MCO):

> *Consequently, when these parts are studied independently from the whole, much can be learnt about them by treating them as if they were machines. This, I believe, is the source of the heuristic power of the MCO, and it explains why this notion has proven to be so successful when used as a methodological tool in the analytical characterization of organisms. To investigate localized areas within the organism as machines allows biologists to conveniently abstract away the intimidating complexity of the broader physiological context of the organism as a whole, and focus their attention on well-defined interacting parts* (Nicholson, 2013, p. 675).

I would like to suggest the inverse of this in relation to Gaia: Gaia has attracted as much controversy because it painfully reminds biologists of the intimidating complexity of the earth as a whole[7].

Nicholson argues that, to effectively evaluate the machine metaphor, one needs to demarcate the heuristic and the theoretical function of the metaphor. Even though the machine metaphor, to Nicholson, provides clear heuristic power in pragmatically simplifying biological systems, it does not provide sufficient theoretical understanding of it (Nicholson, 2013). Likewise, this can be argued for the organism metaphor. Therefore, it follows that the organism metaphor follows the same line - it provides a powerful heuristic tool to research complex environmental systems. However, like the machine metaphor it fails to provide any appropriate theoretical understanding of that reality.

Reductionism, holism and Gaia

The machine/organism distinction can be framed within a larger scientific and philosophical debate: reductionism vs. holism. Gaia, of course, is traditionally grouped within holism and has generally argued to be a holist theory. Part of the reason Gaia attracted the criticism it did was because the scientific community at the time of Gaia's introduction was to a large degree reductionistic, as argued earlier in this chapter. The holist-reductionist discourse has been mapped out by Michael Ruse in his *The Gaia Hypothesis: Science on a Pagan Planet* (, 2015), as has been discussed in the *History of Gaia* subchapter. Now, we can investigate what role the organism metaphor plays in this tension between philosophical positions. Of course, the machine/organism distinction lends itself as a fantastic introduction to this topic, as the machine metaphor is deeply reductionistic and the organism metaphor is very much holistic. The characteristics that define holism – the idea that interacting wholes are more than the sum of elementary particles – follow from the organism metaphor. As stated before, one of the definitive differences between organisms and machines is that parts in an organism

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[7] Here, I would like to make a small sidestep from machines and organisms, to Gaia in relation to complexity. Proctor and Larson discuss that *complexity* itself is a metaphor too. Proctor and Larson argue that the strength of the metaphor of complexity lies in its practical use – it is applicable in current research and policy questions. As Proctor and Larson put it: "*metaphors are not only words that transfer meanings, they also transfer meanings across discourses.*"(2005, p. 1006) To connect this to Gaia, the complexity which Gaia addresses enables a transfer from the complex reality of ecological systems to other discourses, such as policy surrounding ecology and the environment. Proctor and Larson quote Evelyn Fox Keller's following observation: "*scientific research is typically directed at the elucidation of entities and processes about which no clear understanding exists, and to proceed, scientists must find ways of talking about what they do not know – about that [of] which they as yet have only glimpses, guesses, speculations. To make sense of their day-to-day efforts, they need to invent words, expressions, forms of speech that can indicate or point to phenomena for which they have no literal descriptors.*" In a way, complexity is a metaphor to talk about the unknown, that which is too broad to understand by reduction. Complexity is a metaphor that emphasizes and encapsulates a variety of disciplines and how these relate and interact (Proctor & Larson, 2005).

are interdependent on other parts. When parts could somehow be taken out, other parts would lose their properties. This is of course why the organism metaphor was introduced by Lovelock – he wanted to accentuate the interrelatedness of earth, and what metaphor could fit better than the organism to highlight this approach which seemed so deeply holistic? Gaia in scientific discourse became the holist organism which evolved as a single, indivisible process. Gaia can be seen as holist because not the biosphere or the earth alone evolves, but Gaia in its totality does, which is both (Katinić, 2013). And this is exactly where the metaphor of the organism comes in: it makes holism graspable; it simplifies complexity without making it less complex.

This inherent friction between the metaphors of the organism and the machines recontextualize the debates between Lovelock and Margulis and the evolutionary biologists. The organism metaphor provided a shift away from the dominant reductionistic scientific ideas of the time. It stressed the inherent complexity of many biological and ecological processes, which the championed machine-metaphor no longer had sufficient explanatory power for. The organism Gaia signified the need for frameworks and metaphors which uncover and study complex, multi-disciplinary processes. Lovelock was of course repeatedly ridiculed for his organism-metaphor, as has been shown again and again in this paper. Again, when seen in the light of scientific development, it is interesting to recall Kampourakis' notions on scientific development: understanding what something *is not* makes us understand what something *is* (Kampourakis, 2016). Therefore, it is important to talk about why organisms are not machines; why the earth may or may not be an organism; or why the earth may or may not be a machine because of one reason: by understanding what makes one of these not be the other, we may learn more about what the organism, the machine and the earth actually are.

In the holist-reductionist discourse, it is interesting to reconsider the fact that Lovelock was not a holist in the sense that Margulis was, as discussed in chapter 1.2.2. This appears to be in stark contradiction with the holism which Gaia championed, and which it initially attracted its controversy for. In reality, Lovelock's version of Gaia might have lied somewhere in between reductionism and holism. As seen before, this is easy to see in the scientific explanations Lovelock uses – he keeps returning to the mechanistic metaphors he was used to as an engineer. All his feedback loops were deeply mechanistic, and most of the actual holist explanations would come from Lynn Margulis' contributions (Ruse, 2015, p. 189). Lovelock even seems to have reductionistic tendencies in the usage of his organism metaphor. When Lovelock describes the organism metaphor, he stresses that what makes Gaia similar to the organism is feedback loops which are found in organisms, and which keep the salinity, temperature and chemical compositions stable, similar to e.g. an organism's bloodstream.

If Lovelock's Gaia indeed has reductionistic tendencies, both in the systems it describes and the metaphors it uses, can one then not say that Gaia is in fact not holist but reductionistic theory? This is where Margulis comes in once again. Margulis was in fact a holist, from a more alternative school of American biologists raised in the holist tradition. As discussed in the *History of Gaia* subchapter, Margulis' major contribution to Gaia was redefining Gaia as an autopoietic system, which for Margulis was in every essence non-reductionistic: *"unlike mechanistic systems, they* (autopoietic systems)*, produce and maintain their own boundaries."*(Margulis & Sagan, 1997, p. 348). Margulis' autopoietic holism was never meant to be able to coexist with reductionist science, like Lovelock's Gaia. Instead, Margulis' holism refuted such a worldview: "*We compare this pervasive mechanistic belief of biologists, most of whom are smitten by physicomathematics envy, with a life-centered alternative worldview called autopoiesis, which rejects the concept of a mechanical universe known by an objective observer."* (Margulis & Sagan, 1997, p. 266). This stark contrast played a role in the scientific cooperation between Lovelock and Margulis as well. After the initial few papers they wrote collaboratively, they stopped working together. Even though they remained friends, they saw no merit in working together anymore, and somewhat rejected each other's worldviews publicly as becomes apparent in this quote by Lovelock: "*She had no trust whatever in models and mathematics; she thought it was just useless. That's not a good way to collaborate with a physical chemist."*(Ruse, 2015, p. 192). Lovelock and Margulis both published and debated about Gaia on their own after their scientific 'split'. Lovelock kept promoting his reductionism-in-disguise Gaia while always flirting with the idea of the organism Gaia, whereas Margulis held to her holist autopoietic Gaia while always rejecting the organism metaphor.

The introduction of Lynn's Margulis ideas therefore form the next step in the narrative sketched in this paper. The story of Gaia started off with Lovelock's organism, which positioned itself against machine-metaphor based contemporary biology. The organism Gaia and its wanted and unwanted associations drew attention from the evolutionary biologists, who felt Gaia clashed directly with their worldview. Initially, Margulis entered the debate in an attempt to help Lovelock solidify Gaia scientifically, and to have develop a holist framework to research biology through. After a few collaborative papers, Margulis felt that that which gave Gaia its initial scientific attention – Lovelock's organism metaphor – was not needed in Gaia. Lovelock's organism was incompatible with Margulis' own thoughts. Here, we see Gaia's second major development: instead of a feedback system, Margulis developed Gaia towards an autopoietic system and Lovelock and Margulis came to disagree on the nature of Gaia.The organism Gaia can partially be considered a cause for the split between Lovelock and Margulis, and therefore can be seen as a split in directions that Gaia Theory would take.

Gaia, neither holist nor reductionist

There is at least one more important cognitive shift which happens through Gaia Theory, and which has attracted recent attention from contemporary scholars working on Gaia. In a way, Gaia shifts away from the holist/reductionist debate. In this debate, the earth would either be an overarching entity (which the holist vision would suggest) or a sum of the parts (which the reductionist vision would suggest). Bruno Latour suggests that Gaia's radical innovation was that the earth no longer was holist or reductionist, but one complete entity:

> *The Earth's behaviour was inexplicable without the addition of the work accomplished by living organisms, just as fermentation, for Pasteur, cannot be started without yeast. Just as the action of micro-organisms, in the nineteenth century, agitated beer, wine, vinegar, milk and epidemics, from now on the incessant action of organisms succeeds in setting in motion air, water, soil, and, proceeding from one thing to another, the entire climate.* (2009, p. 93).

To this new school of scholars working on Gaia, the fundamental innovation of Gaia was that the earth's ecological conditions (or the abiotic world) and the biota are created by each other – they are one. One is created by the other, and vice versa. There is no inherent order in this Gaia, no reductionism and no holism. Lovelock seems to have realized this implication of Gaia too: "*The atmosphere is not merely a biological product, but most probably a biological construction: not living, but like a cat's fur, a bid's feathers, or the paper of a wasp's nest, an extension of a living system designed to maintain a chosen environment"* (Lovelock, 1979, p. 408). Through this, Gaia becomes a poetic name for distributed processes, which makes the 'unmanageable cacophony of causations' approachable (Dillard-Wright, 2019).

In this modern interpretation of Gaia Theory, a myriad of agencies can be acknowledged while not missing their combined effects. Gaia, they argued, equals seeing both the forest and the trees. This is what Gaia revolutionizes: it refuses to resolve itself in the tension between the whole and its parts. Instead, it chooses to 'remain in the uncomfortable zone where agencies overlap and transform.' (Dillard-Wright, 2019). The innovation here is that instead of demarcating parts which can be studied, every agency leads to another agency. This leads to a vertiginous effect, in which every phenomenon creates something new to be understood (Dillard-Wright, 2019).

Through this, Latour argues, Gaia becomes an anti-system – it only consists of agencies. What role does metaphor play in the understanding of this, as Latour calls it, revolutionary innovation that Gaia brings? It does exactly what Lovelock might have been hinting at all along, even if he could never quite word it outside of reductionist terminology. The organism Gaia makes intuitive what is unintuitive. The line between living matter and non-living matter becomes blurred, and therefore the line between the living and non-living environment does too. This, in a way, follows from the organism Gaia: living beings on our earth become like bacteria in an organism, all playing their own role and exerting their own agency. (Dillard-Wright, 2019) Moreover, it is interesting to consider the godlike superorganism association Gaia evokes in the light of Latour's anti-system: "*Latour stresses that Gaia is a ("finally secular"!) theory of the earth, as it distributes agencies all the way down without the need for providential care."*(Dillard-Wright, 2019, p. 20). Thisgodless system, of course, stands in direct opposition with the godlike association Gaia evokes.

Latour argues that, until Gaia, definitions of nature took the form of trying to fit life forms inside of a larger frame (Latour & Lenton, 2019). Examples of this are Neo-Darwinist natural selection, ecosystems, the biosphere, etc[8]. In all these examples, these concepts *superposition* themselves above life forms, which in turn had no agency compared to the frame which came higher in the order of things. Of course, holism and reductionism fall inside of these concepts too: order is created in the form of top-down or down-up perspectives of reality. However, Gaia has no *order* – it is nothing but what the intertwined agents have been producing through their relations (Latour & Lenton, 2019). Ironically, Latour hereby argues Gaia moves away from an aspect which seems to be the core aspect of the organism metaphor: that of the *superorganism*. Latour does not seem to directly comment in his work on the apparent paradoxical use of terms that arises here, even though he specifically choses the word *superorganism* to describe these other structures as opposed to the organism Gaia[9]. This is similar to the godlike/godless paradox mentioned in the previous paragraph.

Latour does not directly address this paradox, but approaches it in a discussion on the academic interplay between Lovelock and Margulis. In Latour's' words:

> *Even if Lovelock had succumbed to the metaphor of the organism, he would have been redressed by Margulis own long fight against any idea of individual isolated life forms anyway. This is where the collaboration between the two coinventors is so important and under-recognized. Not only does Margulis bring a knowledge of biology and deep time to the conceptual innovation that Lovelock does not possess, but she makes impossible any use of a simplified version of an organism that could reside inside an environment that would be exterior to its history.* (Latour & Lenton, 2019, p. 666).

In this light, the contributions of Lovelock and Margulis can again be contextualized in the development of Gaia Theory. In many ways, they are polar opposites: Lovelock could never quite let go of the organism Gaia, while Margulis always urged him to. If Gaia does indeed situate itself in this 'uncomfortable zone where agencies overlap', Lovelock and Margulis were both searching for a

[8] Latour is of course well known for his work which blurs the nature/culture distinction. In his writings on Gaia, Latour often places *the economy, the state,* and similar terms alongside the more 'natural' terms. To include these or not does not matter for the argument made in this paper, so this nature/culture distinction discussion is excluded here.

[9] Latour does not seem to have clearly defined the word *superorganism* anywhere either, even though he uses it frequently in his work. From what can be made from his fragmented use of the term, superorganisms are most likely intended to be structures such as *nature, culture,* and *economy*, which Latour urges us to move away from.

metaphor that described that uncomfortable zone, both never really able to step outside the language of their respective scientific expertise. In Latour's words:

> *To be sure, this constant shuffling of contradict metaphors interfering with one another is confusing, but it's not a reason to dismiss the theory or to focus on one of the many images the authors proposed. It just means that Lovelock and Margulis have been struggling to find the right way to approach a new historical situation on which they, and the rest of the planet, were embarked.* (2019, p. 667).

Latour argues that the organism metaphor had one more role to play. Lovelock and Margulis, in his view, consciously made the choice not to *over-animate* the earth for some mystical reason[10]. Instead, they refused to *de-animate* it, by which Latour means that the agency of life forms would be denied. (Latour & Lenton, 2019, p. 670). This agency, the potential that every organism has to alter its environment and be part of Earth's history, is what Latour argues Lovelock tried to pursue. It explains for Lovelock why the Earth is not a dead planet. Again, Lovelock finds himself in an awkward position between the reductionistic science he is used to and the mystical views he associated Gaia with:

> *that explains why Lovelock had to resort so often to a somewhat mysterious way of speaking of Gaia as a nonlinear sui generis invention – a solution that had the unfortunate consequence of nurturing a magical "soft" view of a mystical Gaia very far from the hard-nosed fully reductionist view of science that Lovelock was also pursuing.* (Latour & Lenton, 2019, p. 670).

One significant contemporary philosopher, David Abram, worked alongside Lovelock and Margulis, and has published early papers on the perceptual and philosophical implications of Gaia Theory. He seemed to touch upon similar ideas a few decades before Latour and Lenton. Abram wrote *The Perceptual Implications of Gaia* while he was still a student in 1985, which brought him in contact with Lovelock and Margulis. The article argues that Gaia proposes for a new perception of the world, and therefore has "*powerful implications for virtually every realm of scientific and philosophical endeavour*". Abrams argues that, given Gaia's dependency on atmospheric science, Gaia makes us aware of the air around us. Air no longer is merely space between us, it now becomes the life-sustaining fabric in which we move. The significance that Abram attaches to this becomes apparent through the following quote:

> *Let us think about this for a moment. If the perceivable environment is not simply a collection of separable structures and accidental events; if rather, the whole of this environments taken together with myself constitutes a coherent living Being "endowed with faculties and powers beyond those of its constituent parts", then everything I see, and everything I hear, is bringing me information regarding the internal state of another living entity – the planet itself. Or rather about an entity that is both other and non-other, for as we have seen, I am entirely circumscribed by this entity, and am indeed, one of its constituent parts.* (1985, p. 5)

Latour and Lenton's 'myriad of agencies' expresses the same idea: living entities exerting their influence over the natural environment, while the environment exerts its power over said living entities. A distinction cannot really be made – they are not separate parts nor a Whole in which the constituent parts are something greater when combined. The entity is both other and on-other. A difference between Abrams and Latour & Lenton is that Abrams was in favour of the superorganism Gaia, while Latour and Lenton argue that it is an 'awkward' picture to convey an uncomfortable zone in which Gaia exists.

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[10] As is often suggested when Gaia is accused of being a mystical or sentient being.

This new group of scholars working on Gaia are arguably the newest development in Gaia Theory[11], and have recontextualized the idea of the organism Gaia. From the initial organism Gaia, which put Lovelock against the machine-metaphor-using evolutionary biologists, Lovelock and Margulis moved towards a more elaborate Gaia, and eventually split as a result of their disagreement on the metaphor Gaia. Their debate was indicative for the 'uncomfortable zone' outside between holism and reductionism in which Gaia arguably lies. Scholars working on Gaia nowadays such as Bruno Latour and Timothy M. Lenton have picked up on and developed this Gaia further, and have argued that, while the organism Gaia still has 'unwanted' connotations, it can be understood within their contemporary agency-oriented understanding of Gaia. A few things become apparent throughout a history of Gaia[12] such as this one. Gaia never quite comfortably fits within a traditional framework – it is neither fully holist or reductionist, and its wide variety of definitions lead to a complex debate. This is especially the case for the organism metaphor, which never fits quite comfortably throughout Gaia Theory's development.

SoM-Scheme and the Gaia metaphor

In chapter 2.2.1, I have introduced a framework through which the metaphor Gaia can be investigated, similarly to the 'natural selection' case study by David Depew. Now that a narrative of the role of metaphor in Gaia's development has been created, the SoM-scheme can be reintroduced:

1) A principle subject P;

2) A secondary subject S;

3) A set of implications which are associated with S;

4) A set of attributions which P acquires by associating P with S;

5) A set of properties of P which are hidden by associating P with S;

To complete this scheme, I will first discuss the functions of metaphors which Bradie (Bradie, 1999, p. 199) has identified in relation to Gaia. What functions does the organism metaphor possess? How have these played a role in the scientific reception and development of Gaia Theory? After this, I fill in the SoM scheme.

- Is the organism metaphor's function *Heuristic*? As many scholars have argued before, Gaia has value in the epistemic framework it provides. It is a framework which, depending on the specific interpretation one would follow, creates a unique understanding of our natural world, which is neither fully holist nor fully reductionistic. Gaia has paved the way for many new fields of study in ecology, earth sciences and environmental science. The field of Earth System Science (ESS) can arguably be said to have sprung from Gaia Theory (Lenton & Wilkinson, 2003).
  However, one needs to ask whether Gaia heuristic power is a result of the organism *metaphor* or of the contents of Gaia Theory. Of course, developments which happened in environmental and earth system sciences are a result of the scientific developments in Gaia Theory, which would imply that the heuristic power does *not* stem from the organism metaphor. Drawing

[11] With the exception of Doolittle's recent attempts to darwinize Gaia, as seen in (Doolittle, 2017).

[12] This history of Gaia is rather shallow, as it only touches upon some of the major developments in Gaia Theory. Gaia Theory has seen a lot of major and minor developments which are not discussed in this section or paper (e.g. Gaia and 'rebel scientists', Gaia and its influence on Earth System Science). Most of these developments however follow a similar pattern – never does Gaia quite fit inside a framework, and the organism metaphor often plays an important role in these developments.

this conclusion out of this analysis would fall short however, as that would fail to acknowledge the power of a metaphor in the development of a theory. Just like in the aforementioned natural selection case study, the organism metaphor has played a role in the development of the theory, and therefore the metaphor has heuristic power too. The heuristic power that Gaia has lies in its intuitive strength: it is easy to understand and communicates the complex idea of interwoven environments in an easy manner. Even harsh Gaia critics somewhat agree on this heuristic value. Let me recall Kirchner's quote in chapter 1.1.2: "*I would agree with the proponents of Gaia that it may be useful to attempt to speculate about the natural world as if it were an organism. But the question of whether the Earth actually is an organism is neither scientifically meaningful nor scientifically answerable"*.
Kirchner seems to argue that Gaia has heuristic value, but not in the scientific sense. Obviously, this quote falls a bit short in its analysis of the organism metaphor – the 'organism' part of the theory was always a metaphor, therefore asking the question whether the organism Gaia is scientifically meaningful is asking the wrong question. What is interesting is the heuristic value that arises out of the metaphor, which is what Kirchner seems to be hinting at. Combining the previous conclusions, seeing the organism metaphor as something that is outside of the scientific status of Gaia Theory is ridiculous – the organism metaphor has shaped the direction Gaia Theory has taken, and therefore its scientific development is partially a result of the organism metaphor. As a result, the scientific heuristic power that Gaia possesses is also partially the power of its metaphor. The organism/machine debate demonstrates this: seeing the earth as an organism instead of a machine opens up the possibility to study the world in another way, and the more 'interrelated' fields of studying the environment such as Earth System Science are arguably a result of that.

- Is the organism metaphor's function *Rhetorical*? Yes and no. Gaia gets its ideas across quite easily – it is in many ways a metaphor that grants an intuitive understanding of a complex reality. Gaia's rhetorical power extends to both scientific and philosophical fields. Its feedback systems are understood much more easily for the layman when compared to a literal organism, such as one's own body. On a philosophical level, Gaia is provokingly rhetoric. It instantly questions many assumptions about what nature is, what life is and what role humans play on earth. This of course explains its popularity with the grand public (who appreciated Gaia's apparent 'easiness') and scientific and philosophical rebels (who found in Gaia supportive arguments for that which they were arguing against). Thus, Gaia has rhetorical power in the sense of it drawing attention easily and having appeal for the layman. However, when inspected more closely, one could question the rhetorical power of the organism Gaia. The organism metaphor provokes, but to what degree does it get across its ideas? The organism metaphor is arguably relatively ill-suited in transferring what is meant with Gaia. This can be seen both internally in the Gaia debate and external of it. Internally, Margulis and Lovelock strictly disagreed over the use of the organism metaphor – Lovelock kept using it, while Margulis warned Lovelock not too. For Margulis, the organism metaphor had unwanted associations, which would have people misinterpret Gaia. This obviously happened, seeing how neo-Pagans and hippies adopted Gaia without its scientific backbones. Thus, the organism Gaia is rhetorical in the sense that it provokes, but not in the sense that it gets its ideas across very effectively. In her essay on the metaphor Gaia, Sara Matera comes to the same conclusion:

> *in a single word Gaia makes comprehensible something that requires nothing less than complexity theory and cybernetics to be understood. Unfortunately, .. , this represents*

the depth as well as the limit of this idea: the name of the ancient Greek Goddess led a lot of people to embrace the ideas entailed by the theory while leaving puzzled the majority of scientific community. This is why only the so-called "weak" version of Gaia has been gradually accepted while the "strong one" had a larger cultural and political impact,.. (2014, p. 134)[13].

- Is the organism metaphor's function *Theoretical*? Again, yes and no. The *theoretical* function of metaphor serves for explanations and theoretical understanding. This function of metaphors is what makes them 'right' in a scientific context. Gaia is definitely an explanation, albeit a somewhat scientifically inconsistent one, as discussed before. However, metaphors with theoretical functions should not be theoretically *misleading,* despite them being useful practically (Matera, 2014). As Sara Matera puts it, "*Gaia evokes pretty well what this 'new look on life on Earth' is giving rise to a number of pioneering research in systemic ecology, but it does not prove in any way the necessity of this radical change;"*(Matera, 2014, p. 135). Thus, Gaia's theoretical function overlaps partially with the rhetorical function, but the organism Gaia does have its unwanted associations, and can be theoretically misleading. This has been shown in the *Criticism of Gaia* subchapter – many theoretical disputes around Gaia were the result of theoretical assumptions on the grounds of Gaia (metaphorically) being an organism. Bradie argues that the theoretical function of metaphors is 'indispensable' for scientific understanding (Bradie, 1999). Does this hold for the organism Gaia as a theoretical metaphor? I would argue it does not. Gaia has scientifically influenced earth sciences and environmental sciences and has opened up new fields, but this should be placed under the heuristic function, as argued before. Under close inspection, most of the ideas that Gaia proposes can be described within more traditional earth science frameworks too- at least for the weaker versions of Gaia.

Thus, we can say that the organism metaphor's function and therefore power as a metaphor lies within the *heuristic* and the *rhetorical* field. The *theoretical* function of Gaia is harder to defend, as shown above. In this way, the situation of the organism metaphor is quite like the metaphor of natural selection, as outlined in the chapter before: heuristically and rhetorically strong, but not in the theoretical sense. There is of course one fundamental difference between these two cases: Darwin's natural selection uncovered a fundamental mechanism in evolution. Darwin just picked an unfortunate metaphor. The same cannot be said for the organism metaphor, as Gaia and especially its portrayal as an organism are not as scientifically sound as Darwinist evolution is.

Understood in the light of these functions, the development of Gaia Theory is much easier to grasp. The heuristic and rhetorical power of the organism metaphor propelled Gaia towards public fame, and provoked scientists to think outside of the box. The theoretical downsides of the organism metaphor, however, led Gaia to become a controversial theory which always existed close to the border between scientific validity and pseudoscience.

[13] Matera speaks here of the Gaia metaphor and includes the mythological associations which are also attached to Gaia. As explained, I have mainly limited my scope in this paper to the organism metaphor. However, Mater's argument still works when solely focussed on the organism metaphor.

Earlier in this paper, Kostas Kampourakis' *structure-of-metaphor* scheme was introduced. Having investigated the strengths, weaknesses and that which Gaia masks and highlights, we can start filling in the SoM-scheme.

1) A principle subject P: *Earth.*

2) A secondary subject S: *Earth as an organism.*

3) a set of implications which are associated with S: *the organism metaphor argues that:*

> *Earth shows dominantly negative feedback mechanisms between the biotic and the abiotic environment,*
>
> *life forms regulate the negative feedback mechanisms,*
>
> *there is an inherent teleology (as a by-product of natural selection) in co-evolved entity Gaia,*
>
> *life and the environment have evolved codependently.*

4) a set of attributions which P acquires by associating P with S: *the organism metaphor opens possibilities of the earth being seen as:*

> *a sentient being,*
>
> *an interrelated whole,*
>
> *a complex whole,*
>
> *having a goal or end-state,*
>
> *an entity with inherent purposiveness,*
>
> *a vitalist spirit,*
>
> *an entity with inherent order,*
>
> *an entity with no inherent order,*
>
> *an entity which can be understood through mechanistic explanations,*
>
> *a god.*

5) a set of properties of P which are hidden by associating P with S: *Gaia masks the ideas that the earth:*

> *can be reduced to parts,*
>
> *functions like a machine,*
>
> *is an entity with inherent order,*
>
> *is an entity with no inherent order,*
>
> *is an entity which can be understood through mechanistic explanations,*
>
> *a god-less entity.*

There is *one* crucial conclusion that can be drawn from this scheme. The SoM-scheme included quite some contradictory associations in it. The organism metaphor simultaneously implies inherent order[14] and no inherent order[15] in nature and between living and non-living forms. Likewise, the organism metaphor both implies and masks that the earth can be understood through mechanistic explanations. One more example is the theological association that the organism Gaia evokes, while it also implies a complete absence of Gods. Once one realizes that the organism metaphor has the potential to be the source of these strictly contradictory interpretations, this effect can be seen in other discussions surrounding Gaia which have not been mentioned in this paper too. For example, Gaia has both been depicted as our 'saviour' in the climate crisis (Samoraj, 2021), and as Mother Earth who takes 'revenge' on humanity, which is for example argued in Lovelock's 2006 book *The Revenge of Gaia*.

This, arguably, implies that the organism metaphor is too broad. As we have seen, metaphors play an essential role in science, and metaphors should be questioned for their desirability within science. Do they communicate their ideas effectively? Are they not theoretically confusing? If the organism metaphor is compared with some other aforementioned metaphors in biology (such as natural selection and the Selfish Gene), a fundamental difference arises. Both these metaphors do not provide a cognitive frame in which implications which are as contradictory as Gaia's are able to arise. The natural selection metaphor, for example, has the unintended implication of a Creator working behind evolution. Darwin of course meant the opposite, but this conclusion arises from evolutionary theory and not the natural selection metaphor itself. Compare this to the organism metaphor: it makes it possible to arrive at completely contradictory points.

Put in this frame, the controversial status of Gaia becomes even clearer to understand. As the organism metaphor provided an explanation for understandings that were mutually exclusive, controversies and disagreements were bound to take place. In this light, it makes sense that many scientists such as Margulis urged Lovelock to drop the organism component of Gaia. Margulis was not a scientist who wanted science to be without metaphors, but she probably realized how the organism metaphor problematized Gaia and inherently stood in the way of Gaia becoming scientific. With the original organism metaphor, Gaia would forever stay in yet another uncomfortable zone: a zone in which multiple mutually exclusive explanations are possible, which inherently leads to a problematic, incoherent theory. As discussed, organisms as metaphors are generally something that holists (such as Margulis) would promote. In the case of Gaia, however, this metaphor was a poor choice. Not only did Lovelock describe the organism in reductionist terms, the organism metaphor could be moulded to substantiate theories which would oppose the holist Gaia Margulis had in mind.

Yet, the organism metaphor had its positive aspect too: its communicative power. As shown in this paper, the organism metaphor played a crucial role in the public acceptance of Gaia. As a result, the Neo-Darwinists and other scientists felt the need to address Gaia, which would stimulate its scientific development. Therefore, understanding the provocative, communicative power of Gaia is key to understanding Gaia's scientific development *outside* of the public sphere. On the topic of science, Lovelock was in many ways more interested in creating an intuitive metaphor to understand the earth through. The poetic aspects of Gaia were meant as a mental picture, evoking certain naturalistic feelings. Even though Lovelock states that he wants Gaia to be taken seriously scientifically, his insistence on that which makes Gaia scientifically complicated tells otherwise. To substantiate this suspicion, one only needs to recall Lovelock's quote: "*The community of environmentalists include many who claim an ownership of Gaian ideas and they have a case. Jonathan Porritt put it well: Gaia*

[14] An inherent order in relation to the Gaia metaphors stem from holist explanations of the Gaia metaphor, in which the entity Gaia is *more* than either nature or culture or any of these separate entities.

[15] A lack of inherent order in relation to the Gaia metaphors stem from explanations such as Latour's, in which the entity Gaia is *nothing more* than either nature or culture or any of these separate entities. In fact, Gaia implies that there is no distinction for Latour.

is too important as a focus for Green thought and action to be conscripted by science" (Lovelock, 1979, p. xiii). This constant shift of focus between wanting to be scientific and wanting to be outside of science is key to understanding Gaia. Lovelock, being the pragmatic engineer he was, indeed felt that science could act as a (too) strict frame for Gaia. Lovelock's use of the organism metaphor, despite Margulis and other scientists asking him to reject the metaphor, is much easier to contextualize through this idea. A metaphor as broad as Gaia could, for Lovelock, be used for many things. It provoked. It was a tool to re-structure societal ideas – dropping the metaphor would have influenced the societal impact of Gaia.

As Kostas Kampourakis argued, 'wrong' metaphors are essential in the development of scientific theories. By understanding what something is not, or why something is not like something else, we understand much better what something *is.* This aspect is crucial in understanding Gaia's influence on modern earth science and life science. A theory as controversial as Gaia, with a metaphor which attracted crowds but not scientists, forced scientists to enter the debate. Simultaneously, Lovelock and Margulis tried to prove Gaia as best as they could. This has led to many scientific innovations in the aforementioned fields. Even though Gaia proposed many theories which were strictly spoken *incorrect,* it has helped science to now understand what is *correct*. As should be shown well enough by now, the organism metaphor has been a crucial catalyst for the debates and attention Gaia has received, and should therefore be considered crucial in the development of Gaia as a scientific Theory. Without the organism metaphor, chances are most people would not even know of Gaia Theory.

Conclusion

As shown in this paper, the scientific development of Gaia Theory has been a history full of controversial ideas, contradictory definitions and conflicting worldviews. A fair share of these contradictions and controversies can be traced to the 'organism' metaphor, which James Lovelock used to describe his idea of global self-regulating feedback systems. In this paper, I have shown how other scholars have problematized several aspects of this metaphor: its incompatibility with Darwinist theory, its scientific incoherency and how it lends itself to unintended teleological associations. This led to this paper's research question: "*What role has the organism metaphor played in the development of Gaia Theory?".*

Metaphors in themselves are not problematic in science. Rather, they should be understood as tools for science, as they can function as gateways to new perspectives, approaches to better understand complex phenomena, and as communication methods. When discussing metaphors in science, it is more interesting to discuss whether and why a metaphor works or not – what aspects of a reality does the metaphor highlight or mask? In this light, this paper has investigated the development of Gaia Theory. It has identified a few developments which can be linked specifically to the organism metaphor (though realistically this paper only maps out a small part of Gaia's history): the initial reluctance from the scientific community happened partially because of the organism metaphor. Even though the organism was, in essence, nothing but a metaphor, it was incompatible with contemporary scientific ideas. This can partially be explained when this debate is understood as a debate between reductionists and holists, in which understanding the world as an organism stands in direct opposition with a very prevalent idea in fundamental biology at the time. This idea is that the world acts like a machine, and organisms and machines are fundamentally different. Even though both are metaphors, their philosophical consequences reach further. Furthermore, this paper has discussed a more contemporary line of thought concerning Gaia Theory, which argues that Gaia Theory is neither holist or reductionist but should be understood as something that moves away from ontological order, and instead argues that Gaia is about entities exerting agencies. The organism metaphor, as this paper has shown, simultaneously explains and is in contradiction with this idea. This, as the analysis of this study has revealed, is a common theme in the organism metaphor. It lends itself to contradictory statements, as it is arguably too broad to accurately describe a scientific idea. However, as shown, the provocative, communicative power that the organism metaphor possesses is perhaps the main reason why Gaia ever got the attention it did. As we have seen, the answer to the research question is two-sided. The organism metaphor complicated Gaia, and inherently pushed it towards a pseudoscientific status. Yet, it is essential in Gaia becoming the somewhat scientifically 'accepted' version it is now. Like the contradictory association which the metaphor makes space for, so does the development of Gaia itself in many ways feel contradictory.

To conclude, I would like to address the use of metaphors in regard to environmental problems such as the climate crisis. As discussed before, Lovelock understood why Gaia was so quickly embraced by the environmental countercultures. Gaia and its organism aspect could easily be moulded in such a way that it supported environmental thought. Lovelock hoped that Gaia would become a spearhead of these environmental movements, which is likely one of the reasons he deliberately took a different stance in the public sphere than he did in the academic sphere. To illuminate this, one only needs to recall Lovelock's statement on how Gaia is too important for Green thought to be strained by science. In this paper, the ethical and political implications of Gaia have mostly been ignored. However, these implications have also played a fundamental role in the lifespan of Gaia. Given the urgent situation that humanity is in relation to the climate crisis, and Gaia's implications in this field, I would like to speculate on the potential of metaphors in the climate crisis. In chapter 2.2, I discussed that metaphors act as carriers of socio-political norms, and that they can be used as tools to change or restructure societies. In the light of environmental disasters, does Gaia have any merit as a socio-political carrier? In one way, it does. The rhetorical power that Gaia possesses has, as shown, had a massive impact on the grand public. The earth is, through the organism metaphor, no longer a dead planet consisting of physical processes. Latour of course argued that Lovelock and Margulis, through Gaia, refused to de-animate the earth. A living earth calls to action, it shifts responsibility to the Earth's inhabitants. On the other hand, the Gaia organism does not suffice in correct theoretical understanding of the earth, and is too broad to act as a focussed framework to study climate problems through. As shown above, the Gaia metaphor has both been interpreted as a saviour and a revenge of the earth. Given that we desire the human race to prevail, what good is a metaphor which can be interpreted as the worlds revenge? About the machine-metaphor, Robert Rosen says: *´On balance, the Cartesian metaphor of organism as machine proved to be a good idea. Ideas do not have to be correct in order to be good; it is only necessary that, if they fail, they do so in an interesting way'* (Rosen, 1991, p. 248). Likewise, it is fair to make the same statement about Gaia Theory. While Gaia, in most versions, can arguably not be said to be correct, it does fail in an interesting way, as shown in this paper.

For a last note and a further research recommendation, it is interesting to ask what other metaphors would be helpful with regards to the climate crisis. Ideally, one would like a metaphor with the rhetorical power that Gaia possesses, as the climate problem is very much a problem that requires wide-spread collaboration. However, an ideal metaphor would be more focussed than Gaia is. More focus leads to less discussion on definitions and is therefore likely easier to apply. What a 'more focussed' metaphor would look like is too broad a topic for this paper, but would definitely be an interesting topic for further research.

Bibliography

Abram, D. (1985). The Perceptual Implications of Gaia. *Dharma Gaia: A Harvest of Essays in Buddhism and Ecology*, *15*(3).

Abram, D. (1991). The mechanical and the organic: on the impact of metaphor in science. *Scientists on Gaia*, 67–74.

Black, M. (1955). Metaphor. *Proceedings of the Aristotelian Society*, *55*, 273–294.

Bradie, M. (1998). Explanation as Metaphorical Redescription. *Metaphor and Symbol*, *13*(2), 125–139.

Bradie, M. (1999). Science and Metaphor. *Biology and Philosophy*, *14*(2), 159–166. https://doi.org/10.1023/A:1006601214943

Capra, F. (1997). *The web of life: A new scientific understanding of living systems*. Anchor.

Cazzolla Gatti, R. (2018). Is Gaia alive? The future of a symbiotic planet. *Futures*, *104*(July), 91–99. https://doi.org/10.1016/j.futures.2018.07.010

Dawkins, R. (1982). The Gene as the Unit of Selection. In *Cancer Treatment Reviews*. https://doi.org/10.1016/0305-7372(91)90016-S

Deane-Drummond, C. (1996). Gaia as Science Made Myth: Implications for Environmental Ethics. *Studies in Christian Ethics*, *9*(2), 1–15. https://doi.org/10.1177/095394689600900201

Depew, D. (2016). How Do Concepts Contribute to Scientific Advancement? In *Philosophy of Science for Biologists* (pp. 123–145).

Dillard-Wright, D. B. (2019). Gaia Theory and the Anthropocene: Radical Contingency in the Posthuman Future. *Journal of Literary and Cultural Inquiry*, *5*(2).

Doolittle, W. F. (1981). Is nature really motherly? *CoEvolution Quat*, *29*.

Doolittle, W. F. (2017). Darwinizing Gaia. *Journal of Theoretical Biology*, *434*, 11–19. https://doi.org/10.1016/j.jtbi.2017.02.015

Doolittle, W. F. (2019). Making Evolutionary Sense of Gaia. *Trends in Ecology and Evolution*, *34*(10), 889–894. https://doi.org/10.1016/j.tree.2019.05.001

Fracchia, J., & Lewontin, R. C. (2005). The Price of Metaphor. *History and Theory*, *44*(1), 14–29.

Godfrey-Smith, P. (2015). Reproduction, symbiosis, and the eukaryotic cell. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(33), 10120–10125. https://doi.org/10.1073/pnas.1421378112

Kampourakis, K. (2016). Why Does It Matter That Many Biology Concepts Are Metaphors? In *Philosophy of Science for Scientists* (pp. 102–122). https://doi.org/10.1007/978-3-319-26551-3

Kassymova, A. K. (2020). *The Study of Metaphor*. https://doi.org/10.1057/9780230503007_1

Katinić, M. (2013). Holism in Deep Ecology and Gaia-Theory: a Contribution To Eco-Geological Science, a Philosophy of Life or a New Age Stream? *The Holistic Approach to Environment*, *3*(1), 3–14.

Kauffman, E. G. (1988). The Gaia Controversy: AGU'S Chapman Conference. *Eos, Transactions American Geophysical Union*, *69*(31), 763–764. https://doi.org/10.1029/88EO01043

Kirchner, J. W. (1989). The Gaia hypothesis: Can it be tested? *Reviews of Geophysics*, *27*(2), 223–235.

https://doi.org/10.1029/RG027i002p00223

Kirchner, J. W. (2002). The Gaia hypothesis: Fact, theory, and wishful thinking. *Climatic Change*, *52*(4), 391–408. https://doi.org/10.1023/A:1014237331082

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago: University of Chicago Press.

Latour, B. (2009). Facing Gaia: Eight Lectures on a new Climatic Regime. In *Polity Press*.

Latour, B. (2017). Why Gaia is not a God of Totality. *Theory, Culture and Society*, *34*(2–3), 61–81. https://doi.org/10.1177/0263276416652700

Latour, B., & Lenton, T. (2019). Extending the domain of freedom, or why gaia is so hard to understand. *Critical Inquiry*, *45*(3), 659–680. https://doi.org/10.1086/702611

Leaky, R., & Lewin, R. (1996). The sixth extinction: biodiversity and its survival. *Nature*, *382*, 594.

Lennox, J. (2019). Darwinism. Retrieved from The Stanford Encyclopedia of Philosophy website: https://plato.stanford.edu/entries/darwinism/

Lenton, T., & Wilkinson, D. (2003). Developing the Gaia theory: A response to the criticisms of Kirchner and Volk. *Climatic Change*, *58*(1–2), 1–12. https://doi.org/10.1023/A:1023498212441

Lewontin, R. (1996). Biology as engineering. In *Integrative approaches to molecular biology* (pp. 1–10).

Lewontin, R., & Scheuerle, A. (2000). The Triple Helix: Gene, Organism and Environment. *Perspectives in Biology and Medicine*, *43*(4).

Lovelock, J. (1979). Gaia: a new look at life on Earth. *Gaia: A New Look at Life on Earth.* https://doi.org/10.1016/0004-6981(80)90149-3

Lovelock, J. (1986). Geophysiology: A new look at Earth Science. In *The Geophysiology of Amazonia: Vegetation and Climate Interactions* (pp. 11–23).

Lovelock, J. (1991). *Healing Gaia: Practical Medicine for the Planet*.

Lovelock, J. (1998). *Homage to Gaia*. Retrieved from http://books.google.de/books?id=jmhee5jrjEMC

Lovelock, J. (2010). *The vanishing face of Gaia: A final warning. Basic Books.* Basic Books.

Lovelock, J., & Giffin, C. (1969). Planetary Atmospheres: Compositional and other changes associated with the presence of Life. *Advances in the Astronautical Sciences*, *25*, 179–193.

Margulis, L. (2008). *The Symbiotic Planet*. Basic Books.

Margulis, L., & Sagan, D. (1997). *Slanted Truths: Essays on Gaia, Symbiosis and Evolution*. Copernicus Books.

Margulis, L., & Sagan, D. (2000). *What is Life.*

Matera, S. (2014). Gaia Hypothesis: The Metaphor of Planet Earth as a Living System. *Metaphor and Argumentation*, *129*.

Nicholson, D. J. (2013). Organisms≠Machines. *Studies in History and Philosophy of Science Part C :Studies in History and Philosophy of Biological and Biomedical Sciences*, *44*(4), 669–678. https://doi.org/10.1016/j.shpsc.2013.05.014

Niebert, K., & Gropengießer, H. (2015). Understanding starts in the mesocosm: conceptual metaphor as a framework for external representations in science teaching. *Science Education*, *37*(5–6), 903–933.

Onori, L., & Visconti, G. (2012). The GAIA theory: From Lovelock to Margulis. from a homeostatic to a cognitive autopoietic worldview. *Rendiconti Lincei*, *23*(4), 375–386. https://doi.org/10.1007/s12210-012-0187-z

Pigliucci. (2014). Why Gaia? *Ethics and the Environment*, *19*(2), 117. https://doi.org/10.2979/ethicsenviro.19.2.117

Pradeu, T. (2016). Organisms or biological individuals? Combining physiological and evolutionary individuality. *Biology and Philosophy*, *31*(6), 797–817. https://doi.org/10.1007/s10539-016-9551-1

Proctor, J. D., & Larson, B. M. H. (2005). *Ecology , Complexity , and Metaphor*. *55*(12), 1065–1068.

Rosen, R. (1991). *Life itself: A comprohensive inquiry into the nature, origin, and fabrication of life*. New York: Columbia University Press.

Ruse, M. (2005). Darwinism and mechanism: Metaphor in science. *Studies in History and Philosophy of Science Part C :Studies in History and Philosophy of Biological and Biomedical Sciences*, *36*(2 SPEC. ISS.), 285–302. https://doi.org/10.1016/j.shpsc.2005.03.004

Ruse, M. (2015). The Gaia Hypothesis: Science on a Pagan Planet. In *Philosophy, Theology and the Sciences* (Vol. 2). https://doi.org/10.1628/219597715x14369486568572

Rushton, E. A. C. (2008). An analysis of the impact of the Gaia Theory on Ecology and Evolutionary Theory. In *Geoversity*. Oxford Brookes University.

Samoraj, J. L. (2021). *Why is the world sleeping?*

Stead, W. E., & Stead, J. G. (1994). Can Humankind Change the Economic Myth? Paradigm Shifts Necessary for Ecologically Sustainable Business. *Journal of Organizational Change Management*, *7*(4), 15–31. https://doi.org/10.1108/09534819410061351

Taylor, C., & Dewsbury, B. M. (2018). On the Problem and Promise of Metaphor Use in Science and Science Communication. *Journal of Microbiology & Biology Education*, *19*(1). https://doi.org/10.1128/jmbe.v19i1.1538

Tyrell, T. (2013). *On Gaia: A Critical Investigation of the Relationship between Life and Earth*. Princeton.

Walsh, D. (2008). Teleology. In M. Ruse (Ed.), *Oxford Handbook of Philosophy of Biology* (pp. 113–137).

Watson, A. J., & Lovelock, J. E. (1983). Biological homeostasis of the global environment: The parable of Daisyworld. *Tellus*, *35 B*(4), 284–289. https://doi.org/10.3402/tellusb.v35i4.14616

Weart, S. R. (2005). *The discovery of global warming*.

Wilkinson, D. M. (1999). Is Gaia Really Conventional Ecology? *Oikos*, *84*(3), 533–536.