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Soil and Worm: On Eating as Relating

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ABSTRACT *Earthworms and soil combine in an ecotoxicological experiment in the Vrije Universiteit in Amsterdam. To determine the effects of a toxic compound produced by genetically modified broccoli, ecotoxicologists use the earthworm in a standardized test to understand the conditions of the soil. In the experiment a variety of elements are brought together and associated in a stable network, but the worm and the soil do not only associate; rather, the worm emerges entangled in different kinds of relations with the soil, both as bioindicator and as bioturbator. Eating provides a good tool to analyze these relations: keeping close to the tangible materialities of the lab practices, eating highlights the complex, asymmetrical relationality of worm and soil. This pushes the understanding of association that circulates in social theory, bringing back its original critical stance towards given notions of liberal, autonomous agents with renewed empirical strength. Thus eating not only frames worms that emerge from the practices of ecotoxicologists as bioindicators and as bioturbators, but it also offers a different language for what has been called the ‘politics of nature’, or how to bring nature into politics without accepting it as a given. In responding to the question on how to live with our planet, eating reminds us that we would do well to start from practices instead of agency in framing our ‘politics of nature’.*

KEY WORDS: Relationality, networks, eating, politics of nature, association, multiplicity

Introduction

Ecologists tell us that life on this planet is enmeshed in intricate *food webs* through which everything, living and nonliving alike, circulates. In ecology, eating emerges as crucial to the ways in which life-forms relate to each other and with their environment. However, the relations in food webs are unstable, balances

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may easily shift and their overall coherence is frail. Now that a vast proportion of the world's natural resources is being used to feed a growing human population, our relations with our companion species and our environment are emerging as a locus for public debate. Ecological catastrophe looms on the horizon.

In this context, a pressing political question arises: how can we live with our planet? To address this, I argue, it is crucial to rethink relationships. Thus, this article addresses how ecology characterizes eating as a form of relating. What kind of relation does eating unfold?

To get a handle on this question, I refer to a site where ecological knowledge is being used as well as crafted: an ecotoxicology experiment that took place in the Animal Ecology Department of the Vrije Universiteit of Amsterdam between 2010 and 2011. The experiment was devised to assess the effects on the soil ecosystem of a specific kind of genetically modified (GM) crop with an enhanced production of glucosinolates. Plants of the *Brassicaceae* family, like broccoli, synthesize glucosinolates for their protection. When they are damaged, for example by a herbivore who chews on them, the compound is activated by an enzyme and becomes toxic.

This defense mechanism is of direct commercial interest as a 'natural' pesticide. More recently it has also attracted interest in oncology because epidemiological studies suggest that glucosinolates reduce the risk of cancer (Verhoeven *et al.*, 1996). Thus, industrial agriculture, biotechnological interventions, global health and hunger hover in the background of the experiment.

However, while the experiment evokes these specters, it is not directly concerned with them, concentrating instead on the potentially risky, ecotoxic effects of increased glucosinolate production. Consequently, leaving colleagues at Wageningen University to explore the beneficial effects of the newly modified crops, the Amsterdam researchers explore their potentially harmful effects on the soil. To do this, they use earthworms. In their use in knowledge production, these critters resemble other invertebrates used as experimental organisms in science, including insects (Kohler, 1994; Parikka, 2010; Raffles, 2010; Wylie, 2012).

Developing a way of understanding their employment as indicators can not only help us in grasping the way in which we can live with our planet, but will also shed light on the involvement of insects in experimental practices. Still, as we shall see, the specific possibilities that worms allow for deserve our separate attention. These possibilities are orchestrated by guidelines published by the Organization for Economic Cooperation and Development (OECD) and the International Organization for Standardization (ISO), which provide instructions for the use of earthworms in toxicity testing. As the researchers working on the ecotoxicology experiment follow these instructions, they attend to the relation between the soil and the earthworm.

As I trace the practices of the scientists concerned, I ask how worm and soil relate in the experiment and how eating is relevant to these relations. The question prompting my research concerns the modes of living together that these relations suggest. My argument is that the ways in which earthworms relate to the soil might teach us something about how to live together in a world in which relations are

something else than associations. For too long we have been caught up in liberal notions of agency. Attending to eating as a mode of relating might help us to move beyond these notions.

Analytical Perspectives

Humans, Earthworms, Soils

From Darwin's early studies of earthworms' impact on the formation of the *humus* (1881), to Jane Bennett's suggestion in *Vibrant Matter* (2010) that they index how matter acts, earthworms have been a key species for thinking about how humans and others might collectively inhabit the planet. Living buried in their environment, eating and moving through it simultaneously, earthworms allow us to open up notions of agency and relation. In the social sciences, singling out earthworms as worthy of attention resonates with a growing interest in what has been variously called the 'animal' (Wolfe, 2003), 'human/animal interface' (Birke, 2009),¹ 'interspecies' (Livingstone and Puar, 2011)² or 'multispecies' (Kirksey and Helmreich, 2010), 'posthuman' [the classic (Haraway, 1991; Wolfe, 2009)], 'nonhuman' (Callon, 1986), 'other than human' [the seminal (Hallowell, 1960)] or 'more than human' (Whatmore, 2002).

While the genealogies of those terms diverge at least as much as they converge,³ they share an interest in questioning vested accounts of where the boundaries are drawn between humans and nonhumans. This interest points to the impossibility of entities 'in themselves' and the centrality of the notion of relationality that underpins this paper. As Donna Haraway puts it: 'If we appreciate the foolishness of human exceptionalism, then we know that becoming is always becoming *with*—in a contact zone where the outcome, where who is in the world, is at stake' (2008, p. 244). This with-ness, this being always already entangled in relations, begs us to attend to what lies beyond a human singled out from her cosmopolitical ecologies, as Stengers would put it (2010).

Science and Technology Studies played a crucial role in the development of this attention to relations and the subsequent sensitivity to nonhumans. In the 1980s, a group of sociologists of science, championed by Bruno Latour and Michel Callon, began to question the disciplinary 'cuts' that had come to separate hard and soft sciences.⁴ They argued that the objects that one might study do not fit those divisions, but rather form complex entanglements; they proposed 'to follow the imbroglis wherever they take us. To shuttle back and forth, we rely on the notion of translation, or network' (Latour, 1993, p. 3). The focus on networks and associations proved a successful analytic tool. By giving primacy to relations, objects emerged as a result of their associations. In Latour's words:

Even though most social scientists would prefer to call 'social' a homogenous thing, it is perfectly acceptable to designate by the same word a

trail of *associations* between heterogeneous elements. Since in both cases the word retains the same origin—from the Latin root *socius*—it is possible to remain faithful to the original intuitions of the social sciences by redefining sociology not as the ‘science of the social’, but as the *tracing of associations*. In this meaning of the adjective, social does not designate a thing among other things, like a black sheep among other sheep, but *a type of connection* between things that are not themselves social. (Latour, 2005, p. 5)

Focusing on the associations between different things ‘that are not themselves social’ brought nonhumans to the fore, as it made apparent how relevant they are in unexpected places, from scallop fishing to primatology experiments, from pasteurized milk to medical labs. In the social studies of science and in other disciplines, this attentiveness to associations now tends to circulate under the (much discussed) shorthand of Actor–Network Theory. There are many followers and there has been much criticism (for constructive discussions, see Strathern, 1996; Law and Hassard, 1999; Gad and Jensen, 2010).⁵ Many understood ‘association’ far too literally, so that science was cast as just a matter of establishing the right kinds of associations and alliances (cf. Amsterdamska, 1990; Elam, 1999).

Without resorting to such literal readings, the first part of this paper will show the analytical possibilities offered by the notion of associations in describing the ecotoxicology experiment. However, not all relations everywhere can productively be cast in terms of association. The term has its strengths, but it has limits as well. For example, it is not suitable for describing and analyzing all the relational practices that take shape in *eating*.

It is no coincidence that eating is attracting increasing attention and even acquiring a central position in the social sciences.⁶ Eating helps us attend to the situatedness, the materiality and the multiplicity of relations (Stassart and Whatmore, 2003; Mol, 2008; Landecker, 2011; Mann *et al.*, 2011; Strathern, 2012). Hence, in this paper, eating will emerge as crucial to relations while, at the same time, reshaping what we may mean by relating. Attending to *what eating is* in those sites where ecology is done will shift our understanding—first of eating and then, also, of relating.

This reconfiguration of eating and relating allows us to look anew at the ways of ‘living with’ that make up ‘nature’. If we are to learn the lesson of multispecies ethnography and of non-, other than-, more than-, or post-human scholarship, we should not delude ourselves that we can talk about nonhumans ‘in themselves’. What these fields of study have achieved is precisely a shift from the assumption that we know, for example, what a (non)human is, to an attention to what, and how, this (non)human is being done—through some specific practice (Law and Mol, 2008). This shift, I will argue, is crucial in rethinking nature.

This is a lesson to take home if we are to think about how to live with our planet. So far, the attempts to articulate answers to this question, what Latour has famously characterized as the ‘politics of nature’, have neglected many of the

relational complexities from which ‘natures’ emerge and forsaken the original intuition of an altogether alternative version of agency. In fact, there have been many efforts to propose novel, more inclusive ways of bringing ‘nature’ into politics (cf. Latour, 2004; Bennett, 2010). Nevertheless these attempts often employ a ‘democratic’ language and its metaphors, and end up relying on liberal notions of politics.⁷

An evident case is when, speaking about the ‘agency’ of nonhumans, they deploy typical liberal, Western models of an ‘agent’ as a free, bounded subject, thus contradicting more sophisticated accounts of agency (Latour, 1987). Many versions of politics still accept the modernist project of rationalizing politics, with its axiomatic assumption of rational, individual agents and liberal, autonomous subjects. Nevertheless a long tradition of academic scholarship has questioned this notion from many perspectives (cf. Nauta, 1984; Toulmin, 1990; Ferguson and Gupta, 2002; Mouffe, 2005; Tsing, 2005; Mol, 2008—to name a few paradigmatic works).

Here, attending to eating may help. Eating is both more symmetrical (at some point, all eaters will be eaten) and more asymmetrical (at any single moment, an organism either eats, or is being eaten) than liberal associations. Or what else is eating in practices? Pursuit of answers will provide us with another kind of politics and other ways of questioning human–environment relations.

Part I—The Experiment as Association

Earthworm Reproduction Test

The ecotoxicology experiment follows the ‘OECD guideline for the testing of chemicals # 222’. This guideline provides a set of instructions on how to correctly perform a toxicological test on earthworms, to quantify the effect of chemicals on the soil ecosystem. ‘Correctly’, in this case, means in a standardized and reproducible way. Such standardization, effected by organizations such as OECD or ISO (another source of similar guidelines) aims to ensure the production of commensurable data. The guideline describes the ‘principle of the test’:

3. Adult worms are exposed to a range of concentrations of the test substance either mixed into the soil or, in case of pesticides, applied into or onto the soil using procedures consistent with the use pattern of the substance. The method of application is specific to the purpose of the test. The range of test concentrations is selected to encompass those likely to cause both sub-lethal and lethal effects over a period of eight weeks. Mortality and growth effects on the adult worms are determined after 4 weeks of exposure. The adults are then removed from the soil and effects on reproduction assessed after a further 4 weeks by counting the number of offspring present in the soil. The reproductive output of the worms exposed to the

test substance is compared to that of the control(s) in order to determine the (i) no observed effect concentration (NOEC) and/or (ii) EC_x [effect concentration x] (e.g. EC10, EC50) by using a regression model to estimate the concentration that would cause a x % reduction in reproductive output [...].⁸

This definition of the test already brings together a number of different objects: the ‘adult worms’ and their ‘offspring’ are brought into contact with the soil, mixed with the ‘test substance’ according to a variety of methodologies specific to different substances. The outcome of this relation is quantified as effect concentrations of various degrees ‘ EC_x ’. Now take a closer look at the entities mobilized by the experiment.

First, consider the earthworms (Figure 1).

Vignette: The room in which the Animal Ecology Department environmental chambers are located looks like a boiler-room. Stark and functional, it hosts some sinks, a few carts to carry loads to the labs, some tables and, obviously, the chambers. Inside one of these, on neatly organized shelves, there are several polystyrene containers, marked with names and codes. One of them reads: *E. andrei*—adults. These are the earthworms used in the experiment. Elaine, the PhD student performing the experiment, explains to me: ‘Our worms are from the *Eisenia andrei* species; these are dung worms and we keep them in horse dung’. She lifts the dark plastic sheet covering the container. Inside it, a shapeless pile of horse dung quivers with earthworms. Elaine puts on a rubber glove and digs into the dung, revealing a teeming bundle of worms. ‘We have had a lab culture since 2003, which originated from a few worms coming from a company called “ECT oekotoxikologie GmbH”, from Germany’.

Figure 1. *Eisenia andrei* specimen during the experiment. Credit: photo courtesy of Elaine van Ommen Kloeke.

ECT is a German company that develops services, products and research in ecotoxicology that comply with Good Laboratory Practice (GLP). Earthworms are among its specialties. As the company website says: ‘ECT has expertise in the taxonomy of earthworms (*Lumbricidae*), potworms (*Enchytraeidae*), and *Nematoda*. In several projects we have studied ecotoxicological effects on these groups of terrestrial invertebrates in combination with their ecology, distribution, and diversity in the field’.⁹ Earthworms are mobilized as a model organism for testing chemicals and for other ecotoxicological experiments in the OECD guideline.

Earthworms, we learn, are indicator organisms. There are many reasons for this. They are, for example, cheap, small and easy to use in experiments, have few requirements, reproduce quickly and do not live for either too long nor too short a time. More importantly, they are easily standardized.¹⁰ Specific instructions are offered for the ‘culturing of *Eisenia foetida*/*Eisenia andrei*’. These breeding instructions are meant to produce a laboratory culture of homogeneous age and size:

Adult worms between two months and one year old and with a clitellum are required to start the test. The worms should be selected from a synchronized culture with a relatively homogeneous age structure [...]. Individuals in a test group should not differ in age by more than 4 weeks.

Cultures are organized in the environmental chambers according to the average age of the worms, but finding worms of the proper size requires additional work. Wearing rubber gloves, with her hands in the horse dung, Elaine searches for these, washes them, dries them on filter paper and weighs them on the micro-balance. All the measurements are carefully written down, to keep track of everything relevant to the experiment.

Then there is the soil.

Vignette: In the laboratory of the Animal Ecology Department, the experiment starts with what is called the ‘spiking’ of the soil: bags of dry soil are wetted by adding water to reach a standard moisture level and then, with a kitchen blender, the wet soil is mixed while the toxic compound is slowly added to reach the required concentrations. While she is performing this task, I ask Elaine where the soil in the bags comes from:

This is what we call natural soil, but it’s a standardized natural soil, so it comes from a company that prepares it for scientific use. But it used to be agricultural soil of a piece of land somewhere in Germany where they have been collecting the soil and they know exactly what they did to it; and they dried it a bit so it’s free of organisms but it still retains its natural characteristics.

The commercial name of this soil, I learned later, is LUFA 2.2. It is produced by *Landwirtschaftliche Untersuchungs- und Forschungs-Anstalt* (Agricultural

Research and Investigation Institute), in Speyer, Germany. On their website, they describe the characteristics of their products:

Our soils are not mixed together from single components, but are *natural soils of commonly occurring soil types from selected areas in Germany*. They are under agricultural use without application of pesticides, biocidal fertilizers or organic manure for at least 5 years. Mineral fertilizers are used until 3 month before sampling. The soils are normally sampled from 0 to 20 cm depth, prepared and sieved with a 2 mm screen.¹¹

Even if it is not artificial soil as required by the guidelines, it is a standard soil. For this reason LUFA soil is particularly useful: like artificial soil, it underwent a process of standardization, while still preserving some of its ‘natural characteristics’. Since the soil is standardized through a number of procedures and measurements, the experimental variables can be controlled more easily: the temperature, moisture, pH, organic matter content, concentration of the toxic compounds, particle size and nitrogen levels. In these procedures, one particular genealogy of the soil is also cared for in order to preserve ‘its natural characteristics’, and to allow for its standardization.

Thus, the soil in the experiment corresponds to the characteristics advertised by LUFA for a 2.2 soil. The treatments provided by LUFA do not only involve the standardization of these characteristics, they also involve the drying of the soil to free it from organisms. In the experiment, the ‘natural characteristics’ of the soil do not include its microbiota, only its physical qualities, far easier to control and attune to a guideline. LUFA 2.2 soil is processed and standardized, both of which make it easier for Elaine to substitute it to the artificial soil required by the guideline. It also separates the soil from the ecosystem it comes from.

Through this detachment, the components of an ecosystem are separated from each other, so that another, experimental, environment may be reconstructed. In this way ‘the environment’ is introduced into the experiment as a physical object, one characterized by a set of variables that scientists can manipulate as they seek to measure and control their effects on a research organism. Thanks to this work, the relationship of the soil to the other elements mentioned in the guideline network remains stable.

Associations and Their Limits

It is already clear how the worm and the soil do not correspond with the image of self-contained entities. In the experiment, they are present only as entangled with many other entities that allow for their existence and standardization. The same applies to the very experiment itself: it not only involves the soil, the worm and the chemicals, but a wide array of other objects needed to standardize it and

make it travel. In the description of the test, two paragraphs are dedicated to the definition of the equipment needed for it. This includes, in addition to the glass containers for the worms:

10. Normal laboratory equipment is required, specifically the following: drying cabinet;—stereomicroscope;—pH-meter and photometer;—suitable accurate balances;—adequate equipment for temperature control;—adequate equipment for humidity control (not essential if exposure vessels have lids);—incubator or small room with air-conditioner;—tweezers, hooks or loops;—water bath.

This list allows us to picture the number of objects involved in the relation between the worm and the soil in the test. What the guideline offers is a means of standardizing and rendering constant the connections between all these objects, providing a stable syntax for the objects involved in the test. In other words, it creates a network of stable relations.

This is where we encounter the classical notion of ‘association’. The network established by the OECD guideline that Elaine follows allows the crucial test to travel from one lab (where the guideline was established) to the other (the Animal Ecology lab) by standardizing the entities involved and keeping their relations stable. Thus they form what Latour (1987) calls an *immutable mobile*. Immutable because the relation between the elements, the syntax of the network in which they hang together, is stable; and mobile because, thanks to this stability, the network travels: without a guideline, it would not be possible for the toxicological test to take place in the same way in labs all over the world. In the present case, the relations between the ‘normal laboratory equipment’, the ‘toxic substance’, the worms and the soil are all standardized and stabilized. And the ‘OECD guideline for the testing of chemicals’ that stipulates how to standardize them, allows *centers of calculations* to perform experiments in similar ways and thus to generate ‘universal facts’ (Latour, 1987).

The network draws attention to the many relations that are established in the lab and beyond. The relations that unfold by following the network, however, are all relations of association. In this case, then, the relation between the soil and the worm is one of *association* as well. And they do not just relate with each other: the other elements of the network that the guideline stipulates are similarly associated, enrolled and assembled in order to produce hard scientific facts that are able to travel. The relations between entities like soil, worm, equipment, scientists, chemicals, labs and guidelines are *symmetrical* in the sense that no *a priori* ‘spurious *asymmetry* among human intentional action and a material world of causal relations’ (Latour, 2005, p. 76) is presupposed.

All elements are (or can be) critical in the functioning of the network: it is only jointly, and thanks to their relations, that they may work. This way of understanding relations comes from De Saussurean semiotics, which took the meaning of the

terms of a language to depend on their relations of similarity to and difference from other terms. What in semiotics was a system of associations between terms has, in 'Actor–Network Theory', become a system of associations between all kinds of varied elements.

However, in addition to its semiotics heritage, the notion of association has yet another genealogy, coming from the language of classical 'Western' political practice. The term *socius* was linked to a particular politico-economic relationship that helped to shape the growing Roman Republic from 510 BC until the first century BC. *Socii* were the tribes and city-states in the Italian peninsula in a military alliance with Rome whose inhabitants did not enjoy the privileges of full citizens. What bound them to Rome was, in the Latin legal definition, *eosdem quos populus Romanus amicos atque inimicos haberent*. This was a shared definition of allies and enemies or, in modern political terms, a unified foreign policy. Thus the term *socii*, allies, emerges from an opposition with *hostes*, enemies.¹²

While nowadays political relations are spoken about in other terms, the socio-economic use of 'associates' has remained current. Alongside this terminological connection, then, the desire for a symmetric inclusion of all sorts of entities with no *a priori* asymmetries from which this notion emerged situates the act of associating in a more evident political terrain. In a 'democratic' move, to include all entities and encompass all kinds of relation, they are all reduced to mere associations, losing their specificities. After beginning as an inclusive effort, then, this move turns into an exclusion of difference and specificities.

This alternative genealogy of the term clarifies that *association* evokes the strategic action of creating alliances so as to 'ward off enemies'. In this sense, the tracing of associations suggested by Latour allows us to analyze 'science in the making' as a strategic play. While thus opening up the possibility that to study scientific research other entities have also to be taken into account, association is not quite an all-encompassing path to understanding what happens in the lab. Instead, it articulates one particular version of science. While this criticism is far from new (cf. Amsterdamska, 1990; Elam, 1999; Whatmore, 2002; Ingold, 2011), this makes it no less relevant in a context where the question is how to frame a 'politics of nature' that is sensitive to a variety of human/environment relations. With the combination of its De Saussurean and Roman ancestry, the problem with Latour's language of associations is that it analyzes relations in a functionalist way. The syntax of a network needs to 'hold in place *functionally*' (Law, 2002, p. 95) if a test is to work even while traveling from one lab to another, if consistency is to be reached.

However, this kind of strategic functionality is not the only kind of relation relevant to ecological and scientific practices. In the experiment we may learn about other ones. This requires us to carefully attend to the soil and the worm in Elaine's experiment and wonder what kinds of relation they establish.

Part II—Intimacies between Soil and Worm

Testing the Chemicals

The spiking of the soil is a long procedure: mashing up the dry soil, the deionized water and the toxic compound with the blender is time consuming. It is also a critical moment in the experiment: seven paragraphs of the guideline are dedicated to the ‘preparation of test concentrations’ and the procedures for ‘mixing the test substance into the soil’.

19. A solution of the test substance in de-ionised water is prepared immediately before starting the test in a quantity sufficient for all replicates of one concentration. A co-solvent may be required to facilitate for the preparation of the test solution. It is convenient to prepare an amount of solution necessary to reach the final moisture content (40 to 60% of maximum water holding capacity). The solution is mixed thoroughly with the soil substrate before introducing it into a test container.

In the guideline, the soil is now treated merely as an inert substrate. Despite its centrality, without living creatures (taken out of it) and the (possibly) toxic substance (still to be added), it has a neutral connotation. The characteristics of the test substance, then, acquire a central position in the experiment. In the present case, it is the chemical activity of the glucosinolates added to the soil that may produce ‘effects’ on the worms. The spiking of the soil does not just reproduce a stable syntax of elements, but also makes the worms’ death, survival and reproduction become meaningful. Remember that the guideline stipulates that ‘chemicals’ are being tested. It is the effects of these ‘chemicals’ on the worms that become a measure of their toxicity. The section on ‘test duration and measurement’ of the OECD guideline specifies how these effects have to be measured.

37. On Day 28 the living adult worms are observed and counted. Any unusual behavior (e.g. inability to dig into the soil; lying motionless) and in morphology (e.g. open wounds) are also recorded. All adult worms are then removed from the test vessels and counted and weighed. Transfer of the soil containing the worms to a clean tray prior to the assessment may facilitate searching for the adults. The worms extracted from the soil should be washed prior to weighing (with de-ionized water) and the excess water removed by placing the worms briefly on filter paper. Any worms not found at this time are to be recorded as dead, since it is to be assumed that such worms have died and decomposed prior to the assessment. [...]

39. At the end of the second 4-week period, the number of juveniles hatched from the cocoons in the test soil and cocoon numbers are determined using

procedures described in Annex 5. All signs of harm or damage to the worm should also be recorded throughout the test period.

In the test guideline, the worms are a tool that makes it possible to measure the toxicity of ‘the chemical’. In our experiment, worms and soil are used to measure the toxicity of glucosinolates. The worms are indicators of the conditions of the soil; they are living gauges, sensitive tools to measure soil toxicity. They are literally *bioindicators*. As Holt and Miller put it: ‘Bioindicators include biological processes, species, or communities and are used to assess the quality of the environment and how it changes over time’ (2011, p. 8). ‘Indicators’ bring us back to semiotics. According to Peirce (1998, p. 5), the indicator is a semiotic device ‘which show[s] something about things, on account of their being physically connected with them’ (Figure 2).

The classical example of an index is the footprint: it *indicates* the presence of a walker, as the act of walking creates footprints. The index results from a physical relation. What does the worm indicate? If it is dead, its dead body indicates the presence of toxins. It is the specific physicality of the relation between worm and soil that makes the worm a good bioindicator.

All species (or species assemblages) tolerate a limited range of chemical, physical, and biological conditions, which we can use to evaluate environmental quality. Despite many technological advances, we find ourselves turning to the biota of natural ecosystems to tell us the story of our world. (Holt and Miller, 2011, p. 8)

Figure 2. The worms and the soil are weighted together in the course of the experiment. *Credit:* courtesy of Elaine van Ommen Kloeke.

The earthworm shifts from being a living creature, handled with gloves, to being a tool.¹³ As a tool, its functionality depends on the test: worms are functional to scientists who seek to measure the toxicity of the soil. What makes their bodies interesting is that toxic compounds have effects on them. The relation between the soil (with or without different concentrations of glucosinolates added to it) and the worm is visible in what becomes of the worm's body. Is it alive and crawling, or damaged and malfunctioning? 'Any unusual behavior (e.g. inability to dig into the soil; lying motionless) and in morphology (e.g. open wounds) are recorded.' Is it dead or has it disappeared? 'Any worms not found at this time are to be recorded as dead, since it is to be assumed that such worms have died and decomposed prior to the assessment.'

The relation between the worm as tool and the soil to be tested is transformative of the worm's body. And this transformation tells us something about the toxicity of the soil. Thus in this situation the worm–soil relation is not just an association; it is a *vital metabolic relation*.¹⁴ The soil through which the worm moves and that it eats can allow the worm to survive or, rather, cause it to die; for when the worm eats the soil so as to consume the edible parts that are in it, it will, if they are present, also accumulate toxins in its body.

The relation relevant to the experiment is not just one in which the worm eats and the soil is being eaten. Earthworms not only swallow soil, they are surrounded by it as well. They live in it.

Earthworms are able to take up organic chemicals through their skin (1) as well as from their food (2). However, the quantitative contribution of each route remains unclear. As earthworms regularly consume soil, it is difficult to study both routes in isolation in a relevant experimental setup. (Jager *et al.*, 2003, p. 3399)

But although some organic chemicals travel through their skin, the study quoted here also suggests that eating is the main path through which toxins from the soil enter into the worm's body. Which is not to say that bioindication is only about eating, if only because eating never occurs in isolation: it ties up with movement and respiration, and it depends on an emergence in the soil that is part of the worm–soil relation. However, sorting out all the aspects of the relation between soil and worm is not relevant to the scientists and thus not worth their effort. What matters to them is measuring the quality of an environment; and it is in this context that they make use of the relation between a bioindicator and its environment, a relation that is more than just one of association. It has crucial consequences on the life of the organism. It is by assessing these consequences that the scientist evaluates the quality of a given environment, or the environmental impact of a chemical.

As they do so, they need not unpack the character of the relation that they learn from: it becomes apparent in the transformations of the body of the bioindicator. If

the worm suffers or dies, then the quality of the environment is not good enough. (Or, in those tests to establish how a pest might be eradicated, an ‘effective toxin’ has been found.) The relation between soil and worm is visible in its effects on the ‘morbidity’ and the ‘mortality’ of adult worms and on their ‘fecundity (e.g. number of juveniles produced)’.

Thus, Elaine’s earthworms are bioindicators. But they are not just that; they are something else as well.

Affecting the Ecosystem

Vignette: Four weeks after the beginning of the experiment I go back to the lab for the survival check. Elaine retrieves the jars from the environmental chambers and empties them, one by one, into a basin to check for adults that have survived in the soil and weighs them individually, noting the results. The soil that comes out of the jars after the experiment has changed: the horse dung that was carefully placed in a hole in the center of the jar has disappeared, as it has been dispersed in the soil through the worm’s guts. ‘You can really see the effect of the worms . . . Particularly in the low concentrations, you can really see it’s all flat and all these tiny droppings . . . they really change the structure’, Elaine points out to me.

The effect of the worms on the soil, their role in the soil ecosystem, makes the effects that toxins have on them relevant in a different way. Elaine’s project—in which the experiment features—focuses on the soil ecosystem and her interest in the earthworms is directly connected to their role in a ‘healthy soil ecosystem’. This is how her project description begins:

Key to a fertile and healthy soil ecosystem is a high bioturbation rate, rapid decomposition and mineralization. Soil invertebrates that belong to the detrital food web are essential for proper soil ecosystem function. As such, they control carbon and nutrient flows and stimulate plant nutrient uptake.¹⁵

Earthworms are among these critical soil invertebrates. They are, Elaine tells me,

. . . not model species like most scientists would see them, for instance like mice and *Drosophila* . . . Eventually, as we are ecologists, what we like to use are species that are actually important in nature. That’s why we have the worms; although you won’t find these [*E. andrei*] easily in nature, they represent a group that is important.

The worms brought into the experiment have, outside of the laboratory, a crucial function. They are ecologically significant as the ‘biotic factors’ that contribute to the functioning of the soil ecosystem. The functionality evoked here belongs to the ecosystem where the worms partake in the cycles of nutrients which characterize a

‘healthy soil’. Without these invertebrates, the soil would not be fertile, nutrients would not move about and plants would not grow.

The earthworm experiment presented here is only one part of Elaine’s project. She also studies the effects of the GM broccoli (through ‘glucosinolates and the products of their hydrolysis’) on springtails and woodlice, and on the soil community they represent. Each species here is a stand-in for a wider ‘functional group’, a group that shares their role in the ecosystem. Earthworms are particularly significant as their lively activities transform soil structure. ‘Worms turbate the soil; they cause aeration of the soil, but also create structures in it so other organisms can grow there’, Elaine said, underlining the importance of her more-than-model species.

Displacing and mixing sediment particles, earthworms are among the main *bioturbators* of the soil. Bioturbation is the term for changes in the environment that are produced by the presence of life-forms, so that the organism’s ability to modify its environment is central here.¹⁶ The effect of worms on the soil is so evident that Elaine could show it to me while she was counting the survivors.

Here soil and worm appear related in yet another way: they are ecologically and functionally intertwined. If the worms die, the soil ecosystem will lose a critical part of its functioning and be less fertile. As the worms live, they make the soil fertile by swallowing it and excreting it again, Elaine explains. Bioturbators are *ecosystem engineers*.

All organisms affect their immediate abiotic environment in some way, but true ecosystem engineers reveal themselves when their presence or absence has a disproportionately large impact on the ecosystem [...]. In artistic language, one could say that ecosystem engineers effectively function as authoritarian scenic designers, which not only set the stage, but also decide on the play to be performed, and select the potential players that enter the stage. Burrowing organisms meet this criterion. (Meysman *et al.*, 2006, p. 692)

When the functionality of the soil ecosystem is considered, the relation between the worm and the soil emerges as transformative of the soil. If the worms’ bodies do not function properly, neither does the ecosystem. In this way, the worm is part of its environment.¹⁷ Thus, the notion of bioturbator introduces quite a different relation between worm and soil. Here the worm is not deployed as a bioindicator, a tool that allows a researcher to measure the quality of the environment. Instead of being measured, the soil is being changed.¹⁸ The earthworm *turbates* the soil: it is not only an indicator of, but also *does* something to the soil—as becomes clear from the transformations the soil has undergone during the four weeks it was left in the environmental chambers. In this context, the relation of the worms with their environment is, once again, material.

However, instead of being modified by their environment, the worms are the ones that modify. The soil–worm relation operating here is transformative of the environment. Eating is crucial again to what is going on here, but not all by itself, as it is enmeshed with the worm's other activities. Although Darwin managed to avoid the term 'eating' when he introduced the seminal intuition of bioturbation, he brought out the activity involved in a captivating way: 'the whole of the superficial mould over any such expanse has passed, and will again pass, every few years through the bodies of worms' (1881, p. 313). Indeed, it is through incorporating and exorporating the soil that the worms' engineering happens.

Eating Multiple

As we look carefully at the practices of the experiment, the relation between soil and worm emerges as more than an association. It comes in different versions that, while material and intimate, involve worm and soil in different ways. These versions are not so much associations as 'assemblages'. This is an unfortunate translation of Deleuze and Guattari's (1987) *agencement*. The term, according to Phillips, 'designates the priority of neither the state of affairs nor the statement but of their connection, which implies the production of a sense that exceeds them and of which, transformed, they now form parts' (2006, p. 108).

Assemblage is not a felicitous translation: while it explicitly refers to the 'coming together', the 'fitting' of various entities, it fails to convey 'the idea of "agency" or the capacity to produce an effect' (Braun, 2008, p. 671) that is associated with it in the term *agencement*. Thus, rather than favoring one kind of practice, that of becoming allies, *agencement* leaves open the possibility of other modes of getting together. Which mode might these be in the soil–worm relations that emerged from the ecotoxicology experiment?

The scientists working on the experiment use the notions of bioindicator and bioturbator. These notions refer to different relations between soil and worm, in which worm and soil do different things. In the first, the worm is transformed by its soil environment, while in the second one the soil is transformed by the worm. The worm's eating of the soil and the soil's being eaten by the worm are central both times. By insisting on that, by pointing it out, I follow the suggestion of Annemarie Mol, who proposes:

that we draw upon exemplary situations to do with eating as we engage in philosophy. That we play with our food, that is, explore the possibilities of models to do with growing, cooking, tasting and digesting. And that, finally, we infuse our theorizing with food metaphors. Many things will change as we engage in such experiments. (2008, p. 34)

The experiment adds to this a version of nonhuman eating, one that changes and challenges what eating might be. The earthworms in the glass jars eat their way

through the soil, consuming the decaying organic matter and minerals which the soil consists of and being affected by it. They then excrete part of what they have swallowed, enriched by the passage through their guts. Eating and excreting, they turbate the soil, changing its composition and making it more fertile.

At the same time, the soil is entangled in other relations of eating: it feeds plants and contains decomposed organic matter. As soon as the earthworms die, their bodies, too, disappear into the soil as the microbiota of the soil decompose them quickly, leaving just a fleeting trace of mold. In their experiment, the scientists capture all these relations with the notions of bioindication and bioturbation. These notions indicate how the toxicologists may measure the quality of the soil and how the ecosystem may maintain its fertility. They also index two different versions of what eating is.

Bioindication is about the survival and the reproduction of the worm, about ‘mortality’ and ‘fecundity’. It is also about the quality of the soil, about its ‘chemical, physical, and biological conditions’. In this context, the worm is a tool and the soil is a variable to be measured, while eating is a way in which matter is transferred from the soil to the worm. The characteristics of this matter determine the survival and the reproduction of the worm. Eating is a *vital metabolic relationship* in which the earth allows the worm to live—or not. In this material relationship, properties of the soil (notably its toxicity) affect the worm, and the body of the worm is transformed—it thrives on this or dies due to it.

In the ecotoxicology experiment, eating is clearly not a matter of choice: the worms cannot escape their glass jar. Thus their eating appears as an almost passive ‘uptake’ of properties of the soil (including its potential toxicity). But while the ‘uptake’ of toxins from the soil may happen through eating, eating is not alone here; the uptake of toxins may also occur through respiration and through the skin. Figuring out how exactly toxins enter the worm would require specific lab work that may as well be left undone. For this is the point: eating, along with other processes, orchestrates the ‘uptake’ of the chemicals that are the object of investigation.

Bioturbation presents a different version of what eating is. In this case, eating is transformative of the worm’s environment. It brings about changes in the ‘structure’ and the ‘chemical composition’ of the soil. Here the worm is not a research tool, but an agent that moves matter through the ecosystem. It is an engineer modifying its environment and changing it in a way that also affects other organisms. The soil is a structural part of the ecosystem and the worm helps to shape it. For the ecosystem to work, earthworms need to play their part; they need to take up their function as bioturbators.

Here eating is not about the survival of the worm, nor it is about the ‘uptake’ of chemicals. Rather, it is an *ecological relationship*, it is an incorporation/excorporation that ensures the ‘correct functioning’ of the ecosystem. It helps maintain an open enough structure and it recycles matter in a way that assures a ‘healthy’ ecosystem, or a ‘fertile’ land plot.

Again such eating does not occur alone; it is connected to what is absent in the experiment: the rest of the ecosystem. Assessing the character of this connection would require different experiments that are not needed for now. For present concerns, it is enough that eating as bioturbation has a function in the transformation of the environment.

Thus there are two versions of eating linked up with two versions of worms. The relevant activities are different as well. The first worm *measures* the quality (level of toxicity) of an ecosystem, the second *maintains* the quality (structure, components) of an ecosystem. These two modes of acting do not simply add up, if only because they are not relevant in the same site; they pertain to different situations. Attending to bioindication and bioturbation allows us to see that, in some sites, eating is a relation that is vital for the worm, while in others it is functional for the environment: in some sites it transforms the worm, while in others it is the soil that changes.

All these transformations, however, only take place if the jars with earthworm and soil are left to rest, to ferment, to cook, to prove. As Elaine put it when explaining her experiment:

You have these toxic compounds . . . and you just put these compounds in the soil and see *what happens*. See what happens in how quickly is it degrading and what happens to the animals that you exposed to the soil in different concentrations.

A key part of the experiment is leaving the soil and the worm alone for some time, allowing something to happen. The content of the jars, then, is not just the sum of organism and environment, but depends on the process of them being, or rather becoming, together. While the term associations is helpful in highlighting the work of bringing things together, it leaves the question of *how* these things relate, of how they transform each other and become together, unexplored.

Continuing to explore what happens in Elaine's experiment reveals that the relation between soil and worm in this experiment is not just one of association. Instead, the worm eats the soil, partially absorbing it, while the soil is being eaten by the worm, and perturbed. The relation between worm and soil is multiple. And even if the guideline allows the researchers to organize a stable network, the elements that form a part of that network are neither coherent nor unequivocal. A neutral and inert LUFA 2.2 substrate is not quite a soil ecosystem, while a neatly cleaned and weighed earthworm of the *E. andrei* species is not exactly a worm turbating a field. Besides, even if worm and soil and their relations depend upon a number of other entities in the experiment (like the 'normal laboratory equipment' that the guideline stipulates), they are still distinct.

The differences between the elements of the network created in the lab, worm and soil included, are central to their relations. The lab is far from being a homogeneous and symmetrical whole; it includes relations in tension, and its practices involve

changes and multiplicities. Evidently Elaine's experiment depends on much work: it is not easy to put together the OECD guideline, Wageningen GM broccoli, worms, soil and glass jars. But this should not distract us from the work that is being done in the relations between worm and soil. Worm and soil are not just associated, brought together by others, and they do not just associate. Relations of eating are important as well. In the ones unfolded here, worms are bioindicators and/or engage in bioturbation. This makes them different worms, relating to different soils. This, as we shall see, allows in turn for different 'politics of nature'.

Soil, Invertebrates and the Relational Politics of Eating

Instead of carrying with it the Western political ancestry incorporated in the language of associations and political strategy, eating is about processes of material change and exchange which take place inside and between soil and worm. Eating is not just material, it is also relational. It is constitutive, both of the organisms eating and of the ecosystems of which and in which they eat. It is also both creative and destructive, as it may completely transform all the entities involved.

Thus eating calls up a different kind of symmetry since all the elements in the relation change, but in radically different ways. If all goes well, if eating continues, the ecosystem is made fertile, the worm grows and reproduces, and the toxin degrades. As it involves all these changes, eating feeds into the same kind of *asymmetrical reciprocity* offered in Stengers' notion of 'reciprocal capture'. This is

an event, the production of new, immanent modes of existence, and not the recognition of a more powerful interest before which divergent particular interests would have to bow down. Nor is it the consequence of a harmonization that would transcend the egoism of those interests. (2010, p. 35)

This reciprocity depends as much on the differences as on the similarities between the elements involved.

While the specificity of all the entities, and thus their boundedness is relevant, so too is the partial permeability of the various boundaries at stake. The soil and the worm illustrate this perfectly: while the worm is alive, a 'biotic element', the soil is inanimate, it is 'abiotic'. At the same time, the worm may be just a tool, measuring a soil that is a vibrant ecosystem. Eating relates entities that are multiple in a variety of ways, where both difference and similarity are relevant. Thus, it does not just involve asymmetries, but various different asymmetries at the same time. The site, the situation, the event in which practices take place, appear to elicit one version of eating or another.

Because it involves relations that are multiple and asymmetrical, eating may also help us, humans, to think about our own relation with our environment.

We began this article by wondering *how to live with our planet*. Instead of addressing this question with the language of associations, I argue, we should consider that of eating, which evokes relations more intricate than those of being enrolled in a network. In a world multiple, that is neither symmetrical, nor merely asymmetrical, but in which reciprocity and difference come together in a variety of ways, what it means to live *together with* other species is also transformed. Instead of sitting in the same ‘Parliament of Things’, as Latour suggests, or in a ‘Diet of Worms’, as Bennett puts it, it may be better to imagine organisms and environments as eating together or, better still, as eating *each other* and *with* each other.¹⁹

In this sense, the lesson that earthworms teach us is far reaching. They are not only tools for laboratory scientists, but also for social scientists. They can be used to analyze an experiment and the relations that take place in it, as *indicators* of relations and theories; and, simultaneously, earthworms help us recast our conceptual toolbox, modifying our theoretical environment. They *turbate* our theory.

The relevance of interrogating worms in a social scientific article becomes evident. From the practices of earthworms in this experiment, we learn that relations are not necessarily or only associations. We learn that relations may be multiple and asymmetrical, like eating. We learn the importance of the specificities of relations.

But we also learn to shape our own practices and theories by taking nonhumans seriously. Instead of forcing one specific version of politics (i.e. a parliamentary one) on ‘things’, I suggest that we draw on the metabolic relations between earthworms and the soils in which they live. Why impose a ‘democracy’ on nonhumans, when they entertain more interesting relations, relations that are multiple and more complex than the stylized ones that can be found in parliaments?

Instead of shifting from actors to actants, instead of giving voice to nonhumans and representing them politically, we would do well to learn from their situated relationality. Our politics does not need to be built on agency, no matter how well fine-tuned it is to including nonhumans. Instead, our ‘politics of nature’ may attend to diverse practices and draw lessons from them. Practices are what should shape our politics of nature. At a time of ecological concern, thinking about our relation with the planet would be better done in terms of eating practices.

Conclusions

In this article I have considered a specific ecotoxicology experiment and the kinds of relations that it enacted between worm and soil. Thinking about the connections that brought the worm and the soil together in the experiment, the ‘OECD guideline for the testing of chemicals’ emerged as a device that established a stable syntax for the relations between all the elements of the experiment. This is what Latour calls an *immutable mobile*, and the kind of relation established by

the guideline is one of *association*. The strategic construction of a network brings disparate things together, associates them. The soil and the worm end up together in the same jar in the environmental chambers of the Animal Ecology Department thanks to the efforts that established the network of the OECD guideline. All the elements that take part in this network act in a way that allows the structure of their relations to be constant.

However, this is only one of the sets of relations in which the soil and the worms engage. A diagnosis of this limit was already offered by early criticism of the notion ‘association’. In particular, networks are not always stable: the relations between soil and worm can change. They can hold together or fall apart, the worms can die, the soil can stop being fertile. The networks can stop working or they can protract forever in different directions (Strathern, 1996; Law and Hassard, 1999).

But that is not enough. Associations are not the only kinds of relations possible. The entities in a network are not only associated, their relations are many. As we saw, the LUFA 2.2 soil and the *E. andrei* worms are entangled in a number of different relations simultaneously. The differences become evident and relevant when a specific kind of relation is foregrounded in order to achieve something. When measuring the quality of the soil, the worm is an indicator. By cycling the nutrients in the ecosystem, the worm is a turbator. These worms are not mutually exclusive, nor irreducible, but neither are they coherent. Rather, they are different and afford different things.

The same goes for the soil. Soil and worm are multiple and their relations are multiple as well. How *E. andrei* and LUFA 2.2 substrate hold together in the experiment is not singular and clear cut as a term like associations seems to suggest. In the practices of the scientists, the earthworms and the soil various kinds of relations emerge. While they are part of the laboratory network, soil and worm are also, simultaneously, entangled in relations that defy network stability.

We thus need other words for how worm and soil relate in different sites and for different purposes. Following the soil and the worm in Elaine’s experiment, we encountered the entangled practices of bioindicating and bioturbating. These are both fluid and multiple relations that have to do with, and do, eating.

Thus, by following the practices of the ecotoxicology experiment, we learned to think about relations in new ways. This allows us to rethink the politics that shape our cosmopolitical and ecological responsibilities. Putting practices, instead of agency, at the center of our reflections on how to relate with the environment, I conclude, can allow us to reinvent the ‘politics of nature’ in less anthropocentric ways.

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Notes

¹See also the rest of the journal *Humanimalia*, especially its manifesto <http://www.depauw.edu/humanimalia/humanimalifesto.html> (accessed 3 April 2012).

²See also the other articles in the same *Social Text* special issue.

³Tracing their differences is beyond the scope of this article. A good review of the field, although tending more to the geographical, is Braun (2008).

⁴This was, obviously, only one among many concerns that animated the social studies of science. For an overview, see Biagioli (1999).

⁵Such criticisms had already been picked up within the STS tradition earlier on. Mol and Law (1994) offered alternatives to networks in their taxonomy of topologies of relations. In this sense, this article builds on their work, but it does so by grounding the transformative possibilities of relations in the normative problematics of ecological responsibility, as one of the anonymous reviewers pointed out.

⁶This is not to claim that eating escaped the attention of social scientists before this recent renewed interest. In fact, a vast body of literature concerned itself with food and eating, establishing itself both as a distinct discipline (food studies) and as subdisciplines in many fields (anthropology of food, geography of food, sociology of food). The difference lies in the way eating figures—within this more recent wave of interest—in the practices that shape theory and not only as an object of study.

⁷To understand my use of the term ‘politics’ in this article, it is important to keep in mind that this is a conversation with Latour’s *Politics of Nature* (2004) and Bennett’s *Vibrant Matter* (2010). Simultaneously, this understanding of politics can be traced in political theory, for example in Chantal Mouffe’s work (2005), in which the distinction between politics as ‘power’ and as ‘common good’ is made explicit, and ‘liberal politics’ are carefully analyzed.

⁸This quotation, as all the ones below except when differently specified, is from OECD (2004).

⁹From their website <http://ect.de/testing-terrestrial-ecotoxicology/> (accessed 17 August 2011).

¹⁰In this sense, worms are assimilated to insects not only in the popular imaginary, but also in research practices, as they both share the traits that make them useful, interesting and convenient for scientists. The inclusion of earthworms in this special issue on insects, then, is also based on the related uses they share in research, that assimilates them to insects and at the same time explodes the boundaries of such a category.

¹¹From their website, <http://lufa-speyer.de/> (accessed 17 August 2011).

¹²The category of *socius* is central in many works concerned with the socio-political context of Republican and early Imperial Rome; cf. Eckstein (2006).

¹³For an early elaboration on the dynamic between object and tool in the setting of the experimental system, cf. Rheinberger (1995, p. 111).

- ¹⁴For a deep historical analysis of the notion of metabolism, see Landecker (2011) and her forthcoming works.
- ¹⁵From Elaine's project page <http://www.falw.vu.nl/nl/onderzoek/ecological-sciences/animal-ecology/staff/elaine-ommen-kloek.asp> (accessed 17 August 2011).
- ¹⁶An ability that first gained weight in natural sciences in the last work of Darwin, *The Formation of Vegetable Mould through the Action of Worms*, based on studies on earthworms over several years. The functionalism of this ability is evident in this quotation: 'The plough is one of the most ancient and most valuable of man's inventions; but long before he existed the land was in fact regularly ploughed, and still continues to be thus ploughed by earth-worms' (Darwin, 1881, p. 313).
- ¹⁷This is, I suggest, a characteristic that earthworms share with insects: a worlding (cf. Tsing, 2010) specific to insect-like creatures, which can move easily between the scale of the ecosystem and the scale of the individual body. This is facilitated by the apparent identity between individuals, by the large numbers and by the small dimensions, while simultaneously depending on the deep connections between the landscape and the insects (cf. Raffles, 2010). Similar, resonating examples can be seen in Kelly and Lezaun, Tousignant, Beisel and Boete, and Clark (in this volume).
- ¹⁸This is not to be confused with a move from a worm as object to a worm as subject, though. They are not so much subjects, as factors, or, even better, engineers.
- ¹⁹Haraway's notions of 'companion species' and 'messmate' are very productive to think with here (2003, 2008). The meaning evoked by the notion of *cum-panion* is perfectly fitting with the kind of togetherness that the soil and worm seem to point at. Nevertheless, the kind of intimacy that Haraway mobilized, and the kind of human–animal interactions on which she relies are quite different from the nature/nature interactions of organism and environment that this article unfolds. Unfortunately, the question of how to relate these two different, yet entangled approaches, is beyond the scope of this article.

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