

Out of the Metazoic? Animals as a transitional form in planetary evolution¹

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Introduction

In *The Natural Contract* (1995) Michel Serres argued that ‘man’ is becoming a physical variable, weighing down on the Earth in masses, volumes and plates which intervene directly in the operation of the Earth system. Serres suggested that this sheer size and power of humanity meant that it is starting to balance the rest of the Earth – a balancing of one species with all others which is of course an overbalancing. More than half of all accessible fresh water is now used by mankind; more nitrogen is now fixed synthetically and applied as fertilisers in agriculture than is fixed naturally in terrestrial ecosystems (Crutzen and Stoermer 2000); and human-caused erosion and denudation of the continents exceeds ‘natural’ sediment production by an order of magnitude (Zalasiewicz et al. 2008). Around half of the Earth’s land surface has been transformed by cultivation and grazing, the majority of the biosphere has been transformed into intensively used ‘anthromes’, where natural systems are embedded in and shaped by human systems, and human beings now appropriate around 35%-40% of the planet’s production of phytomass (new plant tissues) through photosynthesis (Ellis 2011; Millennium Ecosystem Assessment 2005; Smil 2011). Returning to Serres’ original image of the sheer weight of humanity, Vaclav Smil has given us the chilling calculation that humans now make up 30% of the mass of land vertebrates, and their domestic animals a further 67%, leaving wild animals constituting only 3% of terrestrial vertebrate zoomass (Smil 2011).

It was statistics such as these that prompted scientists Paul Crutzen and Eugene Stoermer (2000) to suggest that humans have become the determining geological force on the Earth, increasingly bending all of its systems to their own purposes and thus pushing the Earth into a new epoch of geological time: the ‘Anthropocene’. Indeed, Charles Langmuir and Wally Broecker (2012) elevated the stakes even higher, by wondering whether we are entering not the *Anthropocene* but the *Anthropozoic*. The 4.5 billion year history of the Earth is conventionally divided into four great aeons – the Hadean, the Archaean, the Proterozoic and the Phanerozoic. Each aeon is further subdivided into eras, the eras into periods, and the periods into epochs, such as the Holocene and the proposed Anthropocene. Langmuir and Broecker’s alternative name for the new unit of geological time would elevate the status of the current transformation of the Earth from that of a change of epoch *within* the Phanerozoic to a change of aeon *from* the Phanerozoic.² They suggest that the rise of intelligent life, a global civilisation and the technological ability to sense and direct the dynamic evolution of Earth systems has produced a potential for planetary change ‘almost as great as that caused by [the] origin of life or the rise of oxygen’ (Langmuir and Broecker 2012: 645). They thus suggest that the transformations described in my opening paragraph might signify the planet moving into a whole new logic of development – in which case, calling this event a mere change of geological epoch would be seriously misleading.

In this chapter I take seriously Langmuir and Broecker’s idea that the Earth may be entering a fifth geological aeon, but suggest that, in order to understand the nature of this shift, the category of being we first need to interrogate as a geological force is not so much *human being* but *animal being*. Only by an investigation into the ‘event’ of animal being in the Earth, I argue, will we be able to understand the character of the aeon that may be passing; but also only through such an investigation can we start to understand exactly how the animal – even in its absence – might also shape the aeon to come. This is not to dismiss the importance of more immediate, normative inquiries into what is happening when one animal so dominates the systems of the Earth that it

seems to turn all other non-human animals into relics of a bygone aeon, to be permitted to live only on its own terms. However, viewed in the context of deep, geological time, the animal becomes a figure not just of lament, but one that enables us to ask a whole other, larger set of questions about the current transformation of the Earth.

For the majority of the philosophical treatment of animals focuses on what the animal means *for the human*. The language of animal rights might try to go beyond the utility of animals to humans, but it still focuses on how our own, human, behaviour ought to be modified by consideration of what animals are and what we thereby owe to them. Other philosophers have asked different questions about animals that go beyond their ethical treatment, more ontological questions about what an animal is (Agamben 2004; Derrida 2008). But their analyses tend still ultimately to ask about the relation between the human and the animal – even if this distinction is seen as internal to the human itself. But rather than asking what the animal means for the human, let us try to ask what the animal means *for the planet*. Undertaking this shift in the way we think about animals and the Anthropocene will not invalidate such philosophical questions about the human–animal relationship – indeed, as we shall see, the question of the human *as* animal will return in a way that might force us to rethink the nature of the Anthropocene, and to conceive of the possible futures of the Earth in new and challenging ways.

The animal

Let me first define what I mean by an animal. In *De Anima*, Aristotle (1961) reasoned that whereas plants have a vegetative soul (in that they are capable of nourishment and reproduction), non-human animals have an animal soul (which also involves the powers of being able to sense and move), and humans have a rational soul, giving them not just those lower powers but also those of speech and abstract thought. Today the generally accepted classification of living things – which of course now includes the microorganisms that were unknown in Aristotle’s day – divides them into two ‘domains’ – the prokaryotes and the eukaryotes – further divided into five ‘kingdoms’.³ All life is based on self-reproducing, metabolising cells enclosed by a membrane, but whereas the oldest two kingdoms of the archaea and bacteria are *prokaryotes*, based on rather undifferentiated cells, and are generally *unicellular*, the other three more recent kingdoms of animals, plants and fungi, are *eukaryotes* – in that their cells have a nucleus and various organelles including the mitochondria and chloroplasts – and are typically *multicellular*, in that the organisms are composed of many cells that are genetic clones but have taken on particular functions within the organism.

I am choosing to refer to animals as ‘metazoa’. Ernst Haeckel coined the term in 1874 to refer to multicellular animals, as contrasted with the ‘protozoa’, which he defined as single-celled animals. The term ‘protozoa’ has fallen into disuse, being merged into the kingdom of bacteria, making ‘metazoa’ a synonym for the kingdom ‘animalia’, the latter now more tightly defined as organisms that are multicellular and have differentiated tissues, are motile (at at least one stage in their development) and have a digestive tract. But we can also usefully draw on the way that the ‘meta-’ prefix can signify ‘beyond’, or self-referentiality. Taking ‘meta-’ in this sense, metazoa are life forms constructed from other life forms – life composed from life, life beyond life. In some sense all multi-cellular life is metazoic in this sense – animals, but also plants (which Haeckel called ‘metaphyta’) and fungi. Indeed, Margulis (1998) and other proponents of symbiogenesis argue that life is *always* compositional in this sense, from the once free-living structures that compose the eukaryotic cell, up to the members of an ecosystem. And even multicellularity itself has emerged a number of times, quite independently, although it only became firmly established amongst the eukaryote plants, animals and fungi (Lenton 2011: 93). But here I will reserve the term ‘metazoa’ to its more conventional definition of multi-cellular animals. However, as I will explain in the next section, I am interested in getting beyond the empirical features that animals possess to ask what forms, and what modes of existence, the arrival of the metazoa brought into the world, whether these forms and modes are likely to continue, and whether they might indeed outlast the metazoa themselves.

As well as the term ‘metazoan’ for a singular animal and ‘metazoa’ for the plural form, we can also use the term ‘*metazoic*’ as an adjective to refer to the state of being a metazoan – but also as a noun to refer to the current aeon in Earth’s development. The official name of this aeon, ‘Phanerozoic’, means ‘visible life’, in reference to the arrival of organisms that were large enough, morphologically complex enough and hard enough to leave clear fossils in the rock record. For the start of the Phanerozoic coincides with the Cambrian explosion, an apparently discontinuous event which saw the rapid emergence and diversification of multicellular, eukaryotic animals (and later plants and fungi), and the establishment of most if not all the phyla and body plans that exist today.⁴ Renaming the Phanerozoic aeon ‘the Metazoic’ would in one sense be a shift that is no shift at all, simply specifying the form of life – the metazoa – whose remains become so visible in the rock record corresponding to that time. But in another sense it would foreground even more sharply the metazoan, the multi-cellular animal, as not just the most geologically visible form of the fourth aeon of the Earth, but the form which defines the aeon’s specificity, and perhaps its lasting significance. It is certainly true that that animals were not simply something that happened to emerge in, adapt to and benefit from the distinctive conditions of the Phanerozoic – from the huge amounts of standing biomass, the complex food webs, and the shift to rapid evolution, ecological succession and biogeographical variation. Apart from being the first of the multicellular kingdoms to emerge, and even though (on the land at least) their mass was to be swamped by that of the plants, their presence played a crucial role in developing the complex ecological nets of the current aeon. As Nicholas Butterfield puts it, ‘animals figure disproportionately in the maintenance of the modern Earth System, not least because they invented it’ (Butterfield 2011: 87).

But in asking about the significance of the arrival of multicellular animal life for the Earth, we have to be careful not to reinstate the idea a chain of being with intelligent humans at the top, in which the emergence of the metazoa was a necessary earlier step. As McShea and Simpson (2011) argue, the common intuition that there is some natural progression observable in the course of biological evolution – from lower to higher, from simpler to complex – may indeed be well-founded; but, as they emphasise, in any attempt to specify the metric that may be increasing there is always a danger of subtly importing prejudices that place humans as the pinnacle and telos of Earth history, or simply being misled by an ‘observer bias’ due to us being a product of the only planet with life that we have yet observed. For the purpose of this paper we will suspend these difficult questions; but we will have to return to them at the end. For, in order to answer the question of what the metazoan might mean for the planet, and what it might mean to ask how we might move out of the Metazoic, we need to have a sense of what if anything about metazoic being is a necessary stage if the planet is to achieve new levels of self-organisation.

It might be said that in my introduction I have sought to bring together taxonomy and chronology by the simple replacement of ‘animal’ by ‘metazoan’, and ‘Phanerozoic’ by ‘Metazoic’, which move has the implication that animals belong to a particular time in the Earth, and that a particular time in the Earth belongs to the animals. But I know that I may have to work harder than this in order to convince the reader that the arrival of the metazoa may have meant something significant for the Earth, or even to formulate the question of what this something was and whether and how it might condition the planet’s future development. So I will continue to use the term ‘Phanerozoic’ where appropriate to describe the current aeon. But also, in the next section, I will seek to explain what I mean by situating the metazoa as forms in planetary time – by asking what animals mean for the planet. For, by asking what animals mean ‘for the planet’, I am not simply trying to make an ecological move, using ‘planet’ in the common vernacular sense of referring to the integrity of the global biosphere, but to open up to a more expansive set of questions.

Planetary evolution and the emergence of form

For me, this resituating and restating of the question of the animal is part of a wider project of establishing the project of the ‘planetary humanities’. While sharing many features and sensibilities with the ‘environmental humanities’, it also has a number of features that makes it distinctive. For

example, a planetary humanities approach is *volumetric*, concerned not just with ecological relations on the surface of the Earth but with relations within and across all the different entangled volumes of the stratified Earth; it is temporally extended into *deep time*, situating contemporary environmental, technological and social changes on geological and astronomical timescales; it involves the investigation of *the planet* as a specific category of being, getting beyond discourses of the Earth's boundedness, fragility or uniqueness to a more general account of the distinctive ontology and temporality of planets as evolving assemblages; and it is engaged with the *interplanetary* – both in the sense of a comparative sensibility to the divergent paths that can be taken even by similar planets, and in an orientation to the multiple ways that the stories of individual planets might become intertwined.

Above all, the approach I am taking here is concerned with the distinctive topological relations and modes of existence made possible by planetary becoming, including elemental compartments, new compositions of matter and energy, new surfaces and gradients, new entities and new kinds of relation. Like Manuel DeLanda, I approach the Earth as an assemblage which has evolved in an ongoing dialectic between the intensive (differences and gradients) and the extensive (form and structure). The Earth has evolved in complexity through a progressive unfolding of singularities, a cascade of symmetry-breaking bifurcations (DeLanda 2002: 17, 20) that took it from being an undifferentiated cloud of atoms and particles to something progressively more anatomical or geometrical. It did this – and continues to do so – through processes of *migrating* (where constituent materials move within the body of the Earth) but also *folding* (where it creates new topological relations with and within itself) (DeLanda 2002: 52); through near-equilibrium processes such as sorting and sedimenting (DeLanda 1992: 142-3) and far-from-equilibrium processes of self-organisation (Bak 1996).

So from a shapeless body dominated by the *intensive* – by gradients of temperature, pressure, density concentration and so on – the Earth developed *extensive* structures, form – what Gilles Deleuze and Felix Guattari (1988) call 'strata'. But the emergence of this extensivity, this internal structure, also creates *new* intensivities, new gradients, allowing the generation of new subsystems, new forms of becoming and so on. The ongoing result is a body which is topologically complex. It thus has its well-known 'spheres' such as those of rock, water, air, life, and the relations and dynamics that have emerged within these spheres and between them. But it has also created new forms, with new properties and new 'modes of existence' (Latour 2013; Simondon 1958), some of which in turn may create possibilities for new self-organising processes to be established, and thus further steps in emergence. The project of classifying these new entities is a complex and open-ended one, to say the least – not least because what count as significant forms and modes of existence can change dramatically when the planet moves from one paradigm (Haff 2013) to another, and because the direction of that emergence is underdetermined, in ways we only dimly understand.

A significant contribution to identifying the major events in the unfolding self-organisation of the Earth was made by John Maynard-Smith and Eörs Szathmáry in their work on the major transitions in biological evolution (Maynard Smith and Szathmáry 1995; Szathmáry and Maynard Smith 1995). Maynard-Smith and Szathmáry argued that, rather than being a smooth and continuous process governed by an enduring set of laws, there have been some highly significant moments of transition in the evolution of life on Earth – changes produced by the evolutionary process that altered the very units of evolution and the mechanisms by which evolution proceeds. While confined to biotic evolution, this problem formulation is otherwise very close to our question of what matters 'for the planet' in its self-organisation; Maynard-Smith and Szathmáry and those responding to their work are asking not what moves the planet up a pre-set, developmental trajectory (since we know so little about the possible developmental trajectories of planets), but what enables the planet to *do new things*. The major transitions that Maynard-Smith and Szathmáry proposed are as follows: from replicating molecules to populations of molecules in compartments; from unlinked replicators to chromosomes; from RNA as gene and enzyme to DNA and protein (i.e.

the emergence of the genetic code); from prokaryotes to eukaryotes; from asexual clones to sexual populations; from protists (early eukaryotes) to animals, plants and fungi (cell differentiation); from solitary individuals to colonies with non-reproductive castes; and from primate societies to language-using human societies (Maynard Smith and Szathmáry 1995; Szathmáry and Maynard Smith 1995).

Before we focus on the emergence of metazoa, it would be useful to dwell on some general features of these or other candidate 'major transitions'. Firstly, all transitions of this magnitude exhibit 'contingent irreversibility' (Szathmáry and Maynard Smith 1995: 228) or hysteresis: they were not inevitable, but once they occurred their significance was such that a reversion to the earlier logic was unlikely or impossible. Secondly, some, at least, represent the emergence of new hierarchical layers of association, and of new 'evolutionary individuals' (such as the emergence of eukaryotic cells in a merger of unrelated microorganisms, or that of plants, fungi and animals from genetically identical cells). Thirdly, some concern a complexification of information and meaning. For Maynard-Smith and Szathmáry, this is about increasing the 'bandwidth' and 'reliability' of inheritance, through the development for example of DNA, sex, or language. But using the concepts of biosemiotics we could say that a better way of capturing this common feature is as the increase of 'semiotic freedom' (Hoffmeyer 1996). With the very origin of the genetic code, crystalline structures themselves gained a new level of semiotic freedom through achieving what Jacques Monod calls 'gratuity' – 'the independence, chemically speaking, between the function itself and the nature of the chemical signals controlling it' (Monod 1972: 78). Monod uses the example of the role that different proteins play in regulating the synthesis of enzymes in the lactose system, but suggests that gratuity had the effect of 'giving molecular evolution a practically limitless field for exploration and experiment' (Monod 1972: 79). But in the course of subsequent major transitions, not only does semiosis develop new levels of freedom from its material substrate, and new levels of meaning; it also starts to have a greater effect on the course of evolution itself. As Jesper Hoffmeyer surmises, 'the anatomical aspect of evolution may have controlled the earlier phases of life on Earth but my guess is that, little by little, as semiotic freedom grew, the purely anatomical side of development was circumscribed by semiotic development and was thus forced to obey the boundary conditions placed on it by the semiosphere' (Hoffmeyer 1996: 61-62). And with the arrival of the Phanerozoic, a whole new level of semiotic freedom and complexity emerged due to the emergence of ecosystems and trophic levels. 'Once ecology occurs, there is no upper limit on the potential hierarchical complexity of life' (Simpson 2011: 222).

Multicellular being

I have now introduced the category of the metazoa, and introduced something of what it might mean to ask about their significance for the Earth. Now let us try to *specify* metazoic being, to see what it was that entered the Earth at some time between the beginning of the Ediacaran and the end of the Cambrian. We will not dwell too long on the question of 'why' animals emerged at this time. The oxygenation of the atmosphere and ocean may have been a necessary condition for the emergence of the energy-intensive metazoa, but it was not a sufficient one (Margulis 1998: 119) – and indeed ocean oxygenation might as much have been the result as the cause of the metazoa (Lenton et al. 2014). More significant as a precondition was surely the earlier emergence of the eukaryotic cell from the successive combination of previously free-living protozoa – the incorporation within an archaean cell of other organisms such as thermoacidophil bacteria (which became the protein-manufacturing mechanisms in the cell) and purple bacteria (that became the mitochondria that provide energy to the cell) (Margulis 1998: 82). Tim Lenton and Andrew Watson see multi-cellularity, cell differentiation and even the emergence of social organisation as mere delayed effects of the arrival of the eukaryotic cell (Lenton 2011: 93). While we might hesitate at implying all-but inevitability in this way, certainly such an idea raises the possibility that some of the major transitions identified by Szathmáry and Maynard-Smith might be more than externally related.

At risk of compressing a vast amount of detail and complexity, and largely setting aside for the time being the other eukaryotes, plants and fungi, the change from bacteria and archaea to the metazoa can be summarised as follows:

- from individual microorganisms to multiple clones of cells in one individual, and the differentiation of tissues;
- from reproduction through mitosis (dividing to create identical cells) and self-cloning to reproduction through meiosis (creating cells with half the chromosomes) and embryo formation;
- from the autotrophic production of energy and osmotic absorption of nutrients to engulfing and processing particles and other organisms : eating;
- from small to large organisms;
- from smaller to greater morphological diversity ;
- from great to restricted metabolic diversity (focused on respiration and secondary metabolites);
- from specialists to generalists, capable of inhabiting a range of environments, and;
- from chemically driven lives and perception to the more complex inhabitation of milieu.

Added together, this set of changes was hugely consequential for the Earth. The arrival of the metazoa was eventually to shift the Earth from a pre-Phanerozoic, biogeographically uniform planet still largely at the mercy of externally imposed physical and chemical conditions, and characterised by low diversification, low extinction, and slow evolution, to a new form of metastability,⁵ generated dynamically from high levels of biomass and energy-use, nutrient recycling, fast evolution, high diversification, and regular extinction events (Butterfield 2007). In effect, the arrival of the metazoa divided two worlds: 'on the one hand, an exclusively microbial world driven largely by physical circumstance and, on the other hand, a Phanerozoic world dominated by engineered biological environments' (Butterfield 2011: 85). What was it about the metazoan as a new form of entity in the Earth that made it so consequential? And what if anything can we infer from this about the lasting significance of metazoic being for the Earth – and about the aeon that might succeed the Metazoic?

Eating

A candidate for the key change here is the evolution of the gut. As Butterfield puts it, the key event that triggered the emergence of the Phanerozoic world was the emergence of 'gut-based multicellular heterotrophy' (2011). The world learned how to eat – and eating is a topological achievement. Single-celled organisms gain their energy chemically, or from sunlight. When they absorb nutrients from their environment they typically metabolise 'osmotrophically', by absorbing them chemically through their membrane. However, some single-celled organisms learned to eat through phagocytosis, a process whereby they engulf a particle or another organism, and process it as a source of nutrients. But in the relatively unstructured internal environment of a prokaryote (the archaea and bacteria), phagocytosis – especially of another lifeform of similar size – is very difficult to achieve without compromising the integrity of the cell. The emergence of phagocytosis about two billion years ago involved the softening of the hard bacterial membrane and the ability to invaginate – to fold part of its membrane *within* the cell, to create internal membranes (Lenton 2011: 92), thereby establishing the condition not only for eating but also to absorbing what would become internal symbionts and eventually the 'organelles' within the eukaryotic cell.

But the metazoa take eating to a new stage. Through multicellularity and cell-differentiation they are able to grow multiple tissues, and to develop a tube from mouth to anus that is designed to process and absorb the ingested food. Echoing the internal folding of the prokaryote membrane, the embryonic metazoan, at the blastular stage (when it forms into a hollow ball of divided cells) has to gastrulate, folding into itself to form the mouth or anus, as well as start to form the other layers and organs of the body-to-come. The arrival of the gut, along with the mouth and jaw, the anus, produced a new relation in the earth – that between predator and prey. It also thereby opened up a whole new 'phase space' for life in the Earth with an open-ended, evolving set of gradients on which

different life forms became arranged – speed, size, hardness, alertness, digestibility, and so on – producing a huge acceleration in the evolutionary ‘arms race’ (Lenton 2011: 286).

Having a mouth, gut and anus tends to go with a particular kind of body plan. Most animals are either radial (with just one, vertical axis of asymmetry) or bilaterian (with two asymmetries – top and bottom and front and back). The radial phyla such as jellyfish and comb-jellies probably evolved first, in the Ediacaran, and floated in a relatively benign environment, but in the Cambrian it seems to be the bilaterians that became the dominant and defining group of metazoa. Eating provides the pressure to move towards and capture prey, favouring bilaterality, and eventually cephalisation – the concentration of sensory equipment towards the newly ‘front’ end.

The sheer size and motion of metazoic bodies was also significant in itself. Being a size that changes the relative strength between different forces such as gravity, surface tension and fluid dynamics is a qualitative shift that affects the way that an organism can move and refrain from moving. But the size of the metazoa also came to matter greatly to the Earth, as the moving metazoa produced far greater ‘bioturbation’, mixing media and moving nutrients across mixing boundaries, and at their death having converted vast numbers of floating microorganisms into sinking corpses that would change the structure of the oceans, from one that was turbid, stratified and anoxic at its depths, to one that was clear, mixed and oxygenated (Butterfield 2011).

Individuality

Given all the different criteria for biological individuality (Clarke 2010), we have to be careful not to start from an assumption that the metazoan is the paradigm individual. It is easy to slip into a discourse of ‘suborganisms’, ‘organisms’ and ‘superorganisms’, as if it was self-evident what is an individual or organism and what is not. Arguably, entities at all levels of the ecological hierarchy can be individuals (Okasha 2011: 59). For Dupre and O’Malley, living functional entities are all ‘associations of a variety of ... lineage-forming entities’ (Dupré and O’Malley 2009: 13). For Margulis (1998) of course, we live on a ‘symbiotic planet’ – life can only survive in association, so a living individual is in some sense a contradiction in terms.

Yet on the other hand we have not to lose sight of the new form of individuality that arrived with the metazoa, and central here was the emergence of mortal individuals. Ronald de Sousa captures the internal relation between metazoa and death when he defines biological individuality such that all ‘true’ biological individuals ‘have been so constructed by evolution as to be necessarily subject to death, by the very logic of the process’ (De Sousa 2005). This adds to the topological specificity of metazoic being by adding not just spatial complexity but also a temporal complexity: the metazoan is not just a tube moving through the world and the world through it; its existence is temporally pinched at the beginning and the end, in a way that was radically new for the entities generated by and within the Earth.

Crucial here is the formation of new ‘bottlenecks’ in reproduction – pinch-points where heredity has to pass through a sub-individual stage before producing a new individual. Such bottlenecks were crucial in enabling greater diversification (for example into more distinct species), and the evolutionary dynamism of metazoic life, and hence the Phanerozoic Earth system. So, just as the arrival of the predator–prey relation was hugely consequential for the Earth, so was that of the parent–child relation. Prokaryotes reproduce mitotically, creating clones from themselves, and can exchange individual genes with each other through ‘bacterial sex’ (Hird 2009). Plants, animals and fungi, by contrast, generally only exchange genetic material during mating, and (in the case of plants and animals) develop from multi-cellular embryos (Margulis 1998: 70). The key feature of the metazoan reproductive bottleneck, itself related to the arrival of sexual reproduction and meiosis, is the strict split between germ and soma – between those cells in the multicellular body which will pass their heredity on to the next generation of individuals (egg and sperm), and those cells which, while multiplying to produce the various tissues of the multicellular body, cannot produce a new individual organism. As Richard Michod and Denis Roze argue, in evolutionary transitions in individuality – such as that in the arrival of eukaryotic cells or multicellular organisms – germ–soma

separation functions to 'export' evolutionary fitness up to the new higher level (in this case the multi-cellular metazoan) by making neither germ nor soma cells capable of evolutionary success on their own, and thus preventing runaway defection of any constituent cells (Michod and Roze 1997).

The result of this development is the emergence of the individual, mortal body with coordinated somatic clone cells that give over their lives to the larger organism, and characterised by a 'downward causation' where the teleonomy of the whole shapes the functioning of the parts (Andersen et al. 2000). The relatively fixed bodyplan of animals as compared to plants and fungi is also itself a clue to the particular way in the metazoa that evolution has solved the problem of how to maintain multicellularity and prevent runaway defection. The metazoa's strict germ-soma division ensures that somatic cells are not totipotent and that any tendency in them to behaviour that does not favour the animal (such as in tumours) cannot be passed directly into a new generation of the organism (Hoffmeyer 2015). But at the same time the articulated topology of the metazoa discussed above also enables it to host an ecosystem of symbionts in its gut and other internal cavities, so that metazoa become complex assemblages of multiple lineages: within the human body, for example, around 90% of the cells and 99% of the genetic diversity 'within' and sustaining the body is microbial (Dupré 2007: 36-7).

Inhabitation

The third aspect of metazoan being that I want to focus on is the emergence of a new way that living things in the Earth came to 'inhabit' both space and time, through developing a sense of their body and actions in space and time. Of course, perception and sensitivity started well before the animals – before the eukaryotes, and even perhaps before the prokaryotes. Prokaryotes themselves react to a range of stimuli, moving towards or away from stimuli such as higher chemical concentrations (chemotaxis), light (phototaxis) or oxygen (aerotaxis), with prokaryotes living in more challenging environments tending to exhibit greater sensitive and intelligence (Nealson 2011: 48, 51). Crucial to prokaryote sensation is the use of alarmones – ribonucleotide derivatives synthesised in response to stresses in the environment such as a lack of nutrients or high temperatures. Alarmones help control metabolism directly, but they are also used to signal stress to other prokaryotes, stimulating collective behaviour. Reconstructions of the evolutionary history of alarmones synthesis suggest that this form of sensation may have even predated the emergence of DNA: the last common ancestor (LCA) of all life forms may have already possessed elaborate sensory systems based on alarmones (Lazcano et al. 2011). Margulis et al. (2011 :12) go as far as to suggest that the very membrane that confers identity to the cell itself may be the start of perception, because of the way that physical stimuli such as touch, sound and chemical changes open or close its ion channels.

So if perception is perhaps as old as the topological enclosure of life itself, let us try to specify what if anything new might have occurred with the emergence of the metazoa. There are different ways of describing what is novel about the awareness of the metazoa – around all of which lurk the danger of unconsciously assuming, not just that the human has a special significance, but what this significance will turn out to have been. Some theorists suggest that the evolution of cell differentiation is necessary for 'observer status' (Lenton 2011: 93) – not least of course the formation of the nervous system and brain. One could try to measure the 'intelligence' of metazoa, or at least their 'processing power' – a computational metric that would imply that the availability of energy was a crucial necessary step for this significant development, for example through the various oxygenation events undergone by the Earth. But let us try to suspend this talk, and be more phenomenological and topological, and remain true to Aristotle's intuition in *De Anima* that the 'anima' which can sense, and maybe think, is also a body. What sort of body can sense and think?

The metazoa did not develop *de novo* their ways of sensing the world and themselves in the world. Metazoan senses still fundamentally rely on the chemical sensitivity mechanisms inherited from prokaryotes and protists (Margulis and Hall 2011). But the metazoa build on these receptors to create a fuller proprioception – an awareness of their body in space and time. In the evolving metazoa, nerves initially evolved as a new kind of tissue that could coordinate movement across a

morphologically and topologically complex body; but with movement then came the need to coordinate the different tissues and parts of the body, and for the body as a whole to sense its orientation and the relative position of its parts. Movement in the multicellular metazoa thus begat proprioception (Sheets-Johnstone 1999). But later movement and sensation were less tightly coupled, and the nervous system – and bodily sensation – developed new roles. Thus when Michel Serres reflects on the location – and even the origin – of consciousness, when one part of his body touches another, he speak (what else) as a metazoan:

I touch one of my lips with my middle finger. Consciousness resides in this contact. I begin to examine it. It is often hidden in a fold of tissue, lip against lip, tongue against palate, teeth touching teeth, closed eyelids, contracted sphincters, a hand clenched into a fist, fingers pressed against each other, the back of one thigh crossed over the front of the other, or one foot resting on the other (Serres 2008: 22)

The folded, multi-cellular metazoan body senses itself, and thus itself in a perceptual space constituted through its proprioceptive powers. Secondly, it comes to sense other things in the world, and itself, as objects (Bataille 1989).

But the metazoan also senses itself *in time*. Crucial here in this constitution of spatio-temporal existence is the evolution of what Henri Bergson (1959), and later Maurice Merleau-Ponty (1962), theorised as ‘habitual body memory’ (see also Casey 1984). Bergson distinguished ‘habit memory’ from ‘recollective memory’: unlike recollection, habit memory is not a representation of a particular past event, but a slow, cumulative ‘sedimentation’ through repetition which builds the depth of the body’s experience of its milieu and of its own possibilities of action. Through building up the habitual body memory, the metazoan body does not just exist in space but actively *inhabits* space through repetition and sedimentation. Furthermore, in habitual memory, past experience is immanent and bodily rather than represented, means that habitual memory is not past but *future* oriented – it is the precondition for *action* (Casey 1984: 281). So that when Heidegger ([1927] 1962) tried to capture human being-in-the-world in terms of Dasein – as finding ourselves ‘thrown’ in a world of things, and oriented towards future projects, he was capturing a very metazoan theme.⁶ The sedimented experience of the moving and acting body in the world provides the perceptual ground for more *complex* or *compound* actions – sequences or nested aggregations of actions undertaken ‘in order to achieve’, or ‘for the sake of’, a particular purpose or goal (Aristotle 1956: 1072 b1-3). Even the bilaterian body-plan gives us the invisible semiotic scaffolding that orders the perception of the self in space and time, and in further dimensions of value and meaning – in terms of higher and lower, forward and backward, near and far, projection and anticipation (MacWhinney 2008).

So we can see that, amongst the forms that the Earth has produced, the large, motile, multicellular, tissue-differentiated gut-based, mortal, bilaterian, proprioceptive metazoan is topologically distinctive in a way that at least gives us a candidate for what it might be that makes the metazoa significant for the Earth. All new levels of association in the evolution of life introduce a new topological complexity to the forms of the Earth: the closing of chemical cycles in autocatalysis; the enclosing of autocatalytic chemicals within a membrane in the proto-cell; the internal ‘ecosystem’ brought into the nascent eukaryotic cell; the way that individual cells ‘belong’ to the multicellular organism. But its tube-like topology and proprioceptive constituting of itself and its spatio-temporal milieu mean that the metazoan inhabits and moves through the world in a distinctive way.

Out of the Metazoic?

But what role might these three, interrelated features of ‘metazoic’ being I have identified above – the moving, eating body in space, the temporally bound individual member of a species, and the sensory, phenomenological world organised into space and time – play in any transition out of the Metazoic? Are these aspects of ‘metazoic being’ merely transitory forms, which may have been consequential for the Phanerozoic Earth system but will be left behind, or at least not definitive, in

any new aeon? Or do they give us clues as to how a new aeon might already be emerging, in contingent but irreversible manner, from the Earth's ongoing self-organisation?

First, I should make a few preparatory observations. We can question whether the Earth ever really *leaves* a time-period such as an aeon, era, period or epoch; perhaps it would be more accurate to say that new aeons and epochs are laid over the old. So, for example, in many ways we have never moved 'out of' the Proterozoic, or even the Hadean: early aeons – and the signature forces that shaped these aeons or emerged from them – still play their part in determining the unfolding of the Earth's unique history. Single-celled organisms (Hird 2009), and the abiotic life of magma plumes (Clark 2011), still subtend the life of the metazoa. Even within the metazoa themselves, archaic forces are at play (Land 2012). The senses of the metazoa still rely ultimately on chemistry-based prokaryote sensitivity mechanisms. And Deleuze's 'machinic phylum' of self-organising physical processes with their power laws manifest at the level of the multi-cellular organism and above, in the extinction events of ecosystems and socio-cultural dynamics of human societies (DeLanda 1992). Thus we could ask what *has already* come 'out of' the Metazoic and will continue to do so.

But could the Metazoic as an aeon be in another sense passing? Is the Anthropocene a firmly metazoic – and thus Metazoic – phenomenon, or does it herald a transition at the scale of aeon? If the Anthropocene thesis is correct, it already represents a major change in the Earth system. But if the planetary transition we are experiencing was elevated to an even *higher* category of geological time-unit – to that of period, era or aeon - this would signify an even greater change. Such is the suggestion of the term the Anthropozoic (Langmuir and Broecker 2012) – or more hopefully the Ecozoic (Berry 1991).

The human to which the 'Anthropo-' suffix in 'Anthropocene' refers is of course a metazoan. If we are entering a geological time unit in the history of the earth in which humans are the main geological force, is this some pyrrhic victory of the metazoa, like the hominin in the Italian animated film *Allegro Non Troppo* (Bozzetto 1976), who runs ahead of the parade of animals marching to Ravel's 'Bolero', to create offscreen the dystopian technological megacity at which the animals arrive in wonder and fear, sensing their obsolescence? Or is this to misunderstand what is happening? If, as some suggest, the apotheosis of the human might also be its apocalypse (Colebrook 2014; Szerszynski 2012; Zalasiewicz 2008), could it also be the apocalypse – or *aufhebung* – of the metazoan and the metazoic itself? If so, what could that possibly mean? Let me conclude by considering three possibilities.

One scenario – probably the most alarming one – is that of ecological collapse and a return to something like the Proterozoic, microbial Earth. It may be that this is an almost inevitable fate for the planet at some point in the future (Butterfield 2011: 85-6). The shift from the Proterozoic to the Phanerozoic was one from a world dominated by astronomically large numbers of tiny organisms exchanging genes and dividing, to one steered by the presence of far smaller numbers of far larger organisms breeding through sexual reproduction. As part of the creation of the ecology-based Phanerozoic Earth system, this brought into being a new member of Deleuze's 'machinic phylum' – cascading extinction events. Like the earthquakes generated by the tectonic system of the earth, extinction events follow a simple power law, showing that the Phanerozoic ecosystem is tuned to a state of self-organised and self-organising criticality (Bak 1996). It is not impossible that the ongoing, anthropogenic, sixth major extinction event, rather than simply being one of the Phanerozoic extinctions arranged along its characteristic power-law curve, is one that will push the Earth out of the Phanerozoic state. Rather than being part of the – often brutal – way that the Phanerozoic system maintains its dynamic metastability, it may be the extinction to end all extinctions. If this were the case, individual, breeding metazoa may still exist in the next aeon of the Earth, but they would have failed to re-establish their influence over the Earth system, in a long recapitulation of Ediacaran conditions.

A second possibility to consider is a continuation of the long-term trend for evolutionary transitions to form higher-level associations composed from the 'individuals' produced in earlier

transitions. Could metazoa combine to produce new functional wholes and evolutionary individuals? Such 'metametazoans' could potentially rise to new levels of semiotic freedom, topological complexity and space-time inhabitation, while also manifesting many of the features of prokaryotic life such as structural immortality and the lateral transfer of heritable information. Of all evolutionary transitions, that to the eukaryote cell was perhaps the great success in producing a new whole – and from genetically distinct parts – due to its small size and success in internalising the incorporated individuals. Even ecosystems could be 'potential, or incipient, higher-level evolutionary individuals' (Simpson 2011: 219). But at higher spatial scales and ecological levels (such as that of the multicellular metazoan body or the social group) it generally seems easier to form highly integrated evolutionary individuals from genetically related 'units'. Collections of metazoa have achieved perhaps their most integrated form – that is, moving furthest along the spectrum from *aggregate* to *group* to *individual* (Simpson 2011) – in the social insects, with their elaborate controls against reversion to the lower level of individuality, including the split between reproductive and nonreproductive member organisms. But in order to genuinely shift out of the Phanerozoic a metametazoan would have to develop radical new powers, and here 'bandwidth' could be the limiting factor. It is striking that science fiction speculations about new levels of individual built out of related metazoa, whether at the level of insect colonies (Martin 1979) or whole planets and galaxies (Stapledon 1937) depend on the development of telepathic communication or technological enhancement radio (Sandberg n. d.).

The mention of technology brings me to the third possibility I want to close with – the idea of a Technozoic aeon. Technology is a phenomenon of life, but not itself alive – in that, it is rather like the viruses, which can be considerably agential, but only when associated with living things. But could this change? Could technology be becoming definitive of the Earth (see Haff 2013)? I would argue that in order to understand the prospects for a future where it is technology – and not humans – that has become the determining force, we have to look both at earlier planetary and evolutionary transitions, and at the specific character of the metazoic being. Technology had its prefigurations even in the Proterozoic, with bacteria developing nanotechnology and metallurgy, and sensory and locomotive apparatuses (Hird 2009). But the technology developed by humans (and to some extent by other animals) is – initially at least – profoundly shaped by its association with metazoa: in its formation into fewer, larger entities (relating to the metazoan body); its extension of the functionality of the limbs and organs and tissues of the multicellular body (arms, fists, fingers, eyes, mouths, ears) (Leroi-Gourhan [1943] 1971; Stiegler 2015); its formation through the combination of multiple 'tissues' (such as the head and handle of a hammer); its later formation of 'individuals', machines divided approximately into species and niches and that evolve more concretised and integrated syntheses of form and function (Simondon 1958).⁷ And the teleonomy of technological beings – their function or 'final cause' – is one that is borrowed from the living things (Nöth 2009).

However, there are signs that technology is becoming less and less conditioned by metazoic being. From their origins as extensions of the metazoic body, to the development of technical 'individuals' with their own 'milieu' that facilitates their function, to forming integrated systems (and systems of systems) that are opaque to the comprehension of any one human, the topology and being of technical objects has changed profoundly and rapidly (Simondon 1958). Some would argue that technology might have already become autonomous (Ellul 1964), tethering us the service of reproduction and evolution of technical artefacts and systems (Haff 2013). In past planetary transitions, the emergence of new kinds of functional and evolutionary entities has usually been contingent on their constituent units losing either the capacity for independent metabolism or reproduction. With our evolving association with technologies, it may be that the balance of dependency over both metabolism and reproduction between us and our artefacts is shifting. Placing this in the long history of the evolutionary transitions of the Earth suggests that the spectre of the revolt of the robots – proposed by the Czech writer Karel Čapek in the 1920 play R.U.R. that coined the word 'robot' (Čapek 2004) – is part of a story as old as the Earth itself.

Notes

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² Within the Cenozoic, all epochs conventionally end in '-cene', including the Pleistocene, the Holocene, and the proposed Anthropocene, which is why changing the name of the proposed new time period from 'Anthropocene' to 'Anthropozoic' would be an elevation in the hierarchy – at least to the level of an era. All eras within the Phanerozoic aeon end with '-zoic', including the current Cenozoic. But, as pointed out above, the names of the last two aeons also end in '-zoic', so 'Anthropozoic' can also stand as the name of the aeon that will *follow* the Phanerozoic, as suggested by Langmuir and Broecker.

³ See Scamardella (1999) for a summary of the debates.

⁴ There have been many debates about the relationship between the metazoa of the Ediacaran and those that appeared later in the Cambrian explosion – see for example (Conway Morris 1998).

⁵ Metastability is a form of dynamic stability found far from equilibrium, such as in the vortex of water draining down a plughole, where form is maintained despite and indeed because of the constant flow of matter and energy.

⁶ As indeed he was in his reflections on organismic finitude.

⁷ Though with bacterial-like lateral transfer of form – see Basalla (1988).

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