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Process Metaphysics and Mutative Life: Sketches of Lived Time

Chapter 4 (Draft). 'Metamorphosis'

Philosophy, Bergson writes, was born of an awareness of the insufficiency of our faculties of perception. Retelling the progress from the early Presocratic thinkers of Miletus, whose reflections 'on nature' were grounded in some sense of the primacy of the elements (water, fire, air), to the Eleatic school's criticisms of change, Bergson traces a fundamental, and lasting, break between our trust in sensory experience and our conviction (and perhaps a hope) of a pure, abstract, reality that transcends our perception. (Bergson 1992, p. 132) However, the connection between matter and thought, percept and concept, remains. Philosophy is always built upon matter and our experience of the world, no matter how dissociated the resulting rarefied abstraction seems from our messy, concrete existence. If our concepts and ideas (to use Kant's demarcations of the understanding and reason) are constructed as a kind of scaffolding for our perceptions, then 'there cannot be *a* philosophy as there is *a* science.' (Bergson 1992, p. 133) Each philosopher augments her concrete experiences with concepts, giving rise to a multitude of philosophies each reflecting the arbitrary choices of its author, whilst the scientist proceeds ever forwards in the drive to boil down reality to its most general essences. Art, by contrast again, aims 'to show us, in nature and in the mind, outside of us and within us, things which did not explicitly strike our senses and our consciousness.' (Bergson 1992, p. 135) Bergson lauds the achievements of the great artists (citing Turner and Corot) for their ability to make us see in things something that we had not noticed before, but when we see through their art, it is now an experience fundamentally changed. What they attain is an extension of the faculties of perception. (Bergson 1992, p. 136) Yet he reserves for philosophy the capacity to refine our perception of things, by concentrating ourselves in an act that is at once 'perceiving and willing' such that our vision of things is expanded. (Bergson 1992, p. 134) The separation between the sensory and the rational, personified in the break between the Milesians and the Eleatics, might be reversed in a renewed effort in metaphysics to perceive and think the nature of change. This separation between the aesthetic and the intellectual and, by extension, art and philosophy, turning on the distinctions between percepts and affects, on the one hand, and concepts on the other, is repeated in Deleuze and Guattari's attempt to answer the question: *What is Philosophy?* Raising the artist and the novelist to the status of *seer* or *becomer*, as Bergson only in part suggests by referring to art's capacity to extend perceptual experience, we find that 'the death of the porcupine in Lawrence and the death of the mole in Kafka are almost unbearable acts of the novelist. Sometimes it is necessary to lied down on the earth, like the painter does also, in order to get to the "motif," that is to say, the percept.' (Deleuze and Guattari 1994, p. 171)

The artist perceives and feels; the philosopher thinks. This age-old scission is unhelpfully hierarchical (gendered, anthropocentric), and is, ultimately, a barrier to the possibilities for philosophy that Bergson hints at but perhaps closes off in his only rudimentary engagements with art. What if the question of the distinction between philosophy, art, and science was to be explored at the level of concrete experience? This would not be an enquiry towards a grand unification of disciplinary traditions that span millennia, but rather one aimed at exploring the possibilities of 'doing philosophy' from an epistemological perspective, and of communicating philosophical ideas from a pedagogical perspective. In her book, *Drawing as a Way of Knowing in Art and Science*, Gemma Anderson sets her work within the context of an 'educational turn' in contemporary art practice, 'combining strong educational motivations and an interest in sharing artistic process rather than product.' (Anderson 2019, p. 9) In a complementary manner, I take as my starting point in this chapter my own use of drawing in order to think through philosophical problems and to convey philosophical ideas to others as an integral part of my pedagogical practice, to question whether drawing and diagram-making can serve as a means of thinking differently about what it means to be a living organism. This is the more 'local' aim of the next two chapters. My interest in drawing here concerns, principally, its activity or enactment, and secondarily, its status or use as a representational form. On both counts, my suggestion will be that the act of drawing diagrams as integral to the explanation of Bergson's theory of consciousness merits further enquiry. Drawing is, in Bergson's sense, part of our enactment of time. We are not 'in' time, in the manner that objects occupy parts of space. We *are* time, unfolding at different speeds. Time, if any 'thing,' is a heterogeneous multiplicity of speeds and slowness (as Deleuze phrases it). Thus, when one draws, one acts and thinks temporally. Each section of this chapter places this set of problems within a broader tradition of integrating art into scientific research.

The first section examines the 'botanical writings' of German Romantic poet, Johann Wolfgang von Goethe, in particular his *Metamorphosis of Plants* (1790), as a significant example of formalism in the history of evolutionary theory and developmental biology. Serving as a backdrop to debates around the claim that 'ontogeny recapitulates phylogeny,' I follow Goethe's assertion of the protean form of the leaf as the basis of all other parts of the plant that plays out a tension between the process of metamorphosis (in line with form) and a 'spiral tendency;' the latter appearing to resist reduction to any particular form, in a movement of growth that might allow us to think of organic development in terms of an ontologically prior Process. In the second section, I turn to Henri Bergson's *Creative Evolution* for his discussion of the methodological shift required for us to truly think and encounter 'life.' The *élan vital*, or 'vital impetus,' proves to be elusive to our habitual methods for encountering our surroundings (and even our own consciousnesses) since our concepts, the tools of human intelligence, are designed to freeze the flow of reality into discrete parts for the purposes of practical action. This cinematographical mechanism works well enough in its purely practical orientation, but it is inadequate for the apprehension of the processes of life, and it calls for a revision of our methodological approaches to the analysis of life. In the final section of the chapter, I trace the above lineage from Goethe and Bergson through to D'Arcy Thompson's *On Growth and Form.* In this work, Thompson promotes the use of principally mathematical visualizations to illuminate the convergence of developmental forms across very different species, expanding further on Goethe's integration of a visual or spatial understanding of organic growth as essential for biological research. I then conclude the chapter with an artist's response to the problem of presenting living processes, referring to Gemma Anderson's practice of 'Isomorphology,' which seeks to liberate classificatory systems from their conventional usage, and to incorporate drawing as a way of meditating on form and function across species and broader physical lines.

1. Metamorphoses

In Stephen Jay Gould's 1977 analysis of the history of developmental biology, *Ontogeny and Phylogeny*, he focuses on the contention of the nineteenth-century champion of Darwinian evolution, Ernst Haeckel, that 'ontogeny recapitulates phylogeny'. Ontogeny refers to the life history of an individual, both embryonic and post-natal. (Gould 1977, p. 483); whilst phylogeny indicates the evolutionary history of a lineage, conventionally depicted as a sequence of successive adult stages. (Gould 1977, p. 484) If ontogeny recapitulates phylogeny, then the growth of an individual mammal, from embryo to adulthood, repeats in its development the adult forms of its evolutionary ancestors. The study of ontogeny was used to yield up clues about the relationships between diverse species, setting them together in a succession of developmental stages within evolutionary trees. From the perspective of the process thought discussed so far in this book, that of Alfred North Whitehead, we might say that the relation between ontogeny and phylogeny presupposes the existence of a formal unity between the microscopic and the macroscopic manifestations of time, but reiterated at the larger scales of the individual organism and the series of species deemed to belong within an evolutionary developmental series leading up to the 'most developed' species. Whether this iterative structure works in the particular instance of the theory of recapitulation will be subject to debate, as we will see in this chapter. For now, let us simply consider Haeckel's work for the principles of biological research that it reflects. As Gould explains, Haeckel writes within an era of biological enquiry underpinned by the observations of increasing complexity during the process of ontogeny and the identification of a scale of species ascending from 'lower' to 'higher' forms, such that 'if there is but one path of ascent to man, and if a human embryo must begin in [Lorenz] Oken's 'initial chaos', then the stages of human ontogeny must represent the completed forms of lower organisms. As Oken stated in his colourful metaphor, what are the lower animals but a series of human abortions?' (Gould 1977, p. 36) However, the assumptions guiding this method, one that infers humanity's gradual emergence from its less developed 'animal' states, are inescapably anthropocentric, perhaps almost to the point of absurdity.

Gould summarizes the influence of Romantic thought on the theory of recapitulation in terms of two guiding beliefs. Firstly, it holds to an 'uncompromising developmentalism' in which nature is seen as irreducible to the properties of matter, progressing relentlessly from an initial state of chaos through to human beings. (Gould 1977, p 36) That is, human beings are the end or pinnacle of a process of evolution that encompasses other, less developed, species that exist alongside them. Secondly, the Romantic view incorporates a concept of harmony and unity between nature and its laws, where 'Man is the highest configuration of matter on earth, but we are indissolubly linked to all objects as the goal toward which they strive. Nature and spirit, the inorganic and organic, are one.' (Gould 1977, p. 36) In the subsequent theory of recapitulation it would follow from this that the stages of development of a human being from embryo to death recall the adult forms of adjoining older and less complex species. We might refer to these two beliefs as an iteration of the ancient philosophical idea of the Great Chain of Being but let us focus on the idea here that Form is ontologically prior to Process. The significance of formalist theories in the history of biology is articulated in another of Stephen Jay Gould's works in the history of science, *The Structure of Evolutionary Theory.* Cited by Gould as a key figure just preceding the development of theories of transmutation in the nineteenth centuries, from Cuvier and Geoffroy, Lamarck, Darwin and Wallace, to Haeckel, Weismann and Eimer, is the German Romantic poet Johann Wolfgang von Goethe.

Goethe cites the botanist Wenderoth for the choice that confronts us in the study of biological development:

> It depends on whether we wish to pursue the plant in its living metamorphosis as a 'something' capable of existence only *in regulated alteration*, or whether we wish to grasp and retain it as something constant, and therefore dead, in one or several widely separated specific situations. (Goethe 1989, p. 114**)**

Favouring the former approach, the focus becomes 'the process by which one and the same organ makes its appearance in multifarious forms,' or the *metamorphosis of plants.* (Goethe 1989, p. 31) The documentation of this process is broken down into the key stages of the developing plant, from seed to stalk and towards the full formation of leaves, to flower and to fruit (inflorescence and infructescence). The development of the leaf which, in the first and second essays on Metamorphosis, underpins the formal organization of all the other stages, dominates the first epoch of metamorphosis. Once complete, the next epoch is that of the flower but, again, with reference back to the leaf as organizing principle, it appears that what were once leaves organized along the shaft of the stem, have now become organized around a fixed centre to form a calyx. (Goethe 1989, p. 42) In this common principle demonstrated in the early stages of plant development, Goethe sees a foreshadowing of 'the natural force by which the inflorescence and infructescence will be effected at a more advanced age.' (Goethe 1989, p. 43) Note that there is already a tension between the formalism of this account, and the concept of metamorphosis (and later the spiral tendency) emerging in passages such as this one:

> By repeating here a remark made earlier, that styles and stamens represent the same stage of development, we can further clarify the cause of this alternate expansion and contraction. From seed to fullest development of stem leaves we noted first an expansion; thereupon saw the calyx developing through contraction, the petals through expansion, and the sexual organs again through contraction; and soon we shall become aware of the maximum expansion in the fruit and the maximum concentration in the seed. In these six steps Nature ceaselessly carries on her eternal work of reproducing the plants by means of two sexes. (Goethe 1989, pp. 60-61)

However, Goethe's essay, if considered within the history of developmental biology, is characterized in terms of its 'proto-formalist' inspiration, anchored as it is in the protean form of the leaf:

> When we consider a plant in relation to its vital force, we see this vitality manifesting itself in two ways: first, through *vegetative growth*, by development of stems and leaves; and next,

through *reproduction*, which is completed in the formation of the flower and fruit. If we examine the growth phase more closely, we see that the plant, as it vegetates and progresses from node to node, from leaf to leaf, is likewise carrying on a type of reproduction, which differs from that occurring in fruit and flower in that it is *successive* instead of sudden, appearing in a series of individual developments. (Goethe 1989, p. 76)

Formal unity underpins a dynamic of contraction and expansion. As Goethe continues, the distinction he draws above between vegetative growth and reproduction is a difference between a movement of *expansion* into stalk or stem and a movement of *contraction* of the parts of the plant into the concentrated form of the flower. (Goethe 1989, p. 77) At this point, it seems to be a somewhat arbitrary choice to prioritize a reading here of *form* over the *processes* of metamorphosis, but I will return to this later.

If we return to the problem of recapitulation (that ontogeny recapitulates phylogeny) the methods of analysis of distinct stages of development from the mammalian embryo to adulthood, like the identification of distinct organs and stages of plant development (Goethe), both presuppose the reducibility of the essence of the organism to fixed states or stages. Goethe, for example, documents each parts of the plant as some permutation, to different degrees of contraction and expansion, of an original or 'Protean' leaf form. One might use observational drawing, as Goethe and then Haeckel advocated, or with more modern techniques in photography and time-lapse photography, to try to capture these stages. But I would suggest that, by (i) looking at Goethe's subsequent writings on the spiral tendency, and (ii) Bergson's theory of memory and duration (in the next chapter), we might identify not only the limitations of the formalist method of thinking, but also the possibilities inherent in it for overcoming those limitations.

2. Spiral and Serpentine Lines

What are the 'spirals' that Goethe speaks of in his Botanical Writings?[1] Some clues can be found in Goethe's appeal to the term *homoeomeriae* from the fragments of the Presocratic thinker, Anaxagoras, whose view of nature included the affirmation that there is no empty space, and that the creation from nothing and destruction into nothing are impossible. He complains of his predecessors (such as Parmenides and Zeno) that they 'do not have a correct view of generation and destruction; for no thing is generated or destroyed; rather, they are mingled and dissociated from existing things. And for this reason they would be correct to call generation mingling and destruction dissociation.' (Barnes 2001, p. 195) Thus, all material things are always made up of many other things, and when they appear to either come into being from nothing, or to be destroyed into nothing, it is only because we cannot physically see the smallest parts of which they are composed. The materials from which all things are made can therefore be said to be homoeomerous; they are 'uniformly what they are *through and through* and *all the way down*.' (Sisko 2010, p. 445) Goethe uses this idea of homoeomereity in the formal biological description of spirals to refer to a part/whole relation that is indicated in, for example, the way in which stem cuttings can be taken from plants, replanted, and then grown as new individuals, thus revealing how '...independent life is attributed to them, also the power to move independently and to assume a definite direction.' (Goethe 1989, pp. 128-29) This is also referred to here as 'vital incurvation.'

Here, we are in fact presented with two interrelated tendencies, the vertical and the spiral. The vertical tendency describes the process from germination, taking root and building up stalks and fibres, and branches. (Goethe 1989, p. 129) Crucially, we start to see an indication of Goethe's aim to overcome a purely physical or physiological description in favour of some sort of impetus, or a true tendency in process terms, where 'the vertical tendency should be looked upon symbolically as a staff, basic to existence and preserving it for a long period' (Goethe 1989, p. 131). The prolongation forwards, or

[1] This section refers to 'The Spiral Tendency' (1831), published one year before Goethe's death; together with a revised version of the 'Metamorphosis' essay (originally published in 1790); and 'On the Spiral Tendency in Plants' (1833; posthumously published from notes made in 1831).

upwards, is exemplified not just in rigid structures of stalks but also in the climbing or creeping forms of vines (e.g. in ivy and bindweed). In contrast to this, the spiral tendency refers to:

> the developmental, reproductory, and nourishing element. As such, it is temporary and almost independent of the vertical; operating in excess, it is soon exposed to ruin, and perishes; joining the vertical, it fuses with it to form a lasting union as wood or some other solid. (Goethe 1989, p. 132)[2]

The spiral tendency that seemed to preoccupy Goethe in the final years of his life was a recurrent image or theme in eighteenth century writings on aesthetics, starting perhaps with William Hogarth's essay 'The Analysis of Beauty' (1753). As Sabine Mainberger observes, Hogarth affirmed 'the existence of a standard smoothly curved line that can be found everywhere' across works of art of the Classical period, in leaves, flowers, and the bodies of animals in their basic forms and in their posture and movement. (Mainberger 2010, pp. 203-204) Compare now Bergson's essay on 'The Life and Work of Ravaisson,' in which he cites Félix Ravaisson's particular appreciation of the drawings and underlying methodology of Leonardo da Vinci:

> There is, in Leonardo's *Treatise on Painting*, a page that Ravaisson loved to quote. It is the one where the author says that the living being is characterised by the undulous or serpentine line, that each being has its own way of undulating, and that the object of art is to render this undulation distinctive. […] True art aims at portraying the individuality of the model and to that end it will seek behind the lines one sees the movement the eye does not see, behind the movement itself something even more secret, the original intention, the fundamental aspiration of the person: a simple thought equivalent to all the indefinite richness of form and colour. (Bergson 1992, pp. 229-30)

In the next section, I do not simply want to suggest that 'art' is the solution to the problem of presenting the priority of process over form (time over space). After all, Bergson's comments on intuition constitute his contribution to the debate about the role of philosophy in the wake of the rapid development and cultural ascendancy of the empirical sciences, a debate to which Kant's response was to establish the transcendental grounds of experience and thus the limits of philosophy. I do grant that there is merit in pursuing the visual significance of the spiral and serpentine forms, but I am interested here in the attempt to describe biological 'Process,' and the challenges this poses to written and diagrammatic modes of presentation. In this respect, Bergson's diagrammatic presentations of memory enact some of the problems I have summarized in Goethe (and the ideological lineage to which Goethe's botanical writings belong). Two aspects of Bergson's philosophy are brought to mind: (i) the critique of the cinematographical mechanism of thought, and (ii) the theory of intuition as the possibility of encountering duration freed from the fetters of the intellect.

(i) Bergson's critique of the cinematographical illusion, as he names it in the fourth chapter of *Creative Evolution*, commences with a critique of the reductionism characteristic of formalist models of development, whereas 'in reality the body is changing form at every moment; or rather, there is no form, since form is immobile and the reality is movement.' (Bergson 1998, p. 319) It is not any single one of the particular forms, but rather the process of continual change, that is real. In the perception of changes in the organic body we cannot help but take snapshot views on the process. Such changes

[2] The sense of the spiral tendency that I am exploring has a rather different emphasis than Goethe's own, which associates the vertical and spiral with male and female characteristics: '…the vertical and spiral systems are closely bound together side by side in the living plant. When we see that the vertical system is definitely male and the spiral definitely female, we will be able to conceive of all vegetation as androgynous from the root up. In the course of the transformations of growth the two systems are separated, in obvious contrast to one another, and take opposing courses, to be reunited on a higher level.' (Goethe 1989, p. 145) As ludicrous as the comparison sounds, even here the potential to overcome the gender stereotyping at play is contained in the fact of plant androgyny or hermaphroditism; ultimately, neither sex is dominant nor sufficient in isolation, but instead represents a duality abstracted from the androgynous whole.

tend to be so subtle that what emerges from our perception of them are 'a single mean image' that serves as a generalization of our real experience of continual, barely perceptible, change. This generalizing tendency is the source of essentialism. What Bergson calls here the cinematographical illusion is that aspect of human thought that enables the retrograde movement of truth, or the confusion of the method of analysis for the movement analysed. In his critique of this function, Bergson dismantles what for us, over one hundred years later, is now such a familiar process that perhaps the illusory quality of motion captured on film, and the layering of traditional celluloid with digital technology, is even more deeply embedded in our everyday understanding of the nature of perception than it was for Bergson's readers. Whilst the interventions of digital technology into our understanding of perception are interesting in themselves (and I explore this further in the next chapter), the analogy between the cinematograph (the camera) and the human intellect is still effective in making a very simple point about the secondary status we have tended to grant to process. For example, a film of a horse running across the screen, in its composition of a series of still photographs of it, gives us a sense of motion that is not contained in any of the successive images themselves, but in the *apparatus* that lends its own motion (its mechanical movement) to the static images. Consider Georges Canguilhem's subsequent critique of the hierarchy of machines over organisms. (Canguilhem 2008) We cannot compare organisms to machines except somewhat tautologically. Machines that appear to be self-driving simply hide their dependency on some organic source of energy because they rely upon some form of energy-storage. The automaton relies upon this illusory status of the machine, and to compare animals to automata would be simply to compare them to other kinds of animals. The comparison defers the question of the *source* of motion. Bergson's analogy of the cinematograph anticipates Canguilhem's critique in the mistaken ascription of motion to a mechanism in which the real source of that motion is obscured. Likewise, and as a fundamental part of our processes of perception, our mind fixes movements into static images and then reconstructs them into a semblance of mobility: 'Whether we would think becoming, or express it, or even perceive it, we hardly do anything else than set going a kind of cinematograph inside us.' (Bergson 1998, p. 323) Whilst the cinematographical mechanism of thought is an illusion, it is a *useful* illusion, according to which we carve up our surrounding reality in order to better navigate it. It does, however, mean that we risk reducing reality to a set of rigid concepts.[3]

(ii) Bergson's theory of intuition opens up questions about our available strategies for overcoming the illusory mechanisms of thought. Bergson's perspective on the role of philosophy does not supplant, but rather complements, the function of the intellect. His writings on what this intuitive function might be are somewhat scattered and do not form a single, cohesive prescription for thinking about process. As Isabelle Stengers writes rather acerbically, there is a tendency amongst philosophers to place themselves at the terminal point of the traditions to which they respond. Bergson is guilty, on this view, of setting himself up as the unification of the tendencies of the intellect and instinct by trying to exemplify his own theory of intuition. (Stengers 2011, p. 115) Yet Stengers' defence of Whitehead from this tendency should equally apply to Bergson's thought: what is important is not the status of any particular philosophy within the context of its history. What is interesting, rather, is an 'adventure of reason' that is 'not a definition of reason, but a particular description of the historical process that exhibits what we call "reason" as one of its questions.' (Stengers 2011, p. 115) In Bergson's case, the historical process is an evolutionary one, in which life itself has evolved as an exploration of its own encounters with the world, manifested in a plurality of forms of life that each blend different degrees of intellectual and instinctive contact with things. As Bergson asks:

> What, then, is the principle that has only to let go its tension,—may we say to detend,—in order to extend, the interruption of the cause here being equivalent to a reversal of the effect ?

[3] This is not only a matter of making category mistakes within the confines of philosophical or scientific reflection. It extends to our treatment of other species, in which such reductionism manifests, at its worst, in the forms of violence we visit upon them, reducing them to objects of study in the laboratory, or to units of production within an agricultural system. What possibilities might arise in our capacity to think, and in our attitudes towards other species, if we were to confront the tendencies of the intellect with the processual source of its concepts?

> For want of a better word we have called it consciousness. […] In order that our consciousness shall coincide with something of its principle, it must detach itself from the already-made and attach itself to the being- made. It needs that, turning back on itself and twisting on itself, the faculty of seeing should be made to be one with the act of willing,—a painful effort which we can make suddenly, doing violence to our nature, but cannot sustain more than a few moments. (Bergson 1998, p. 237-38)

An analysis of life, and of consciousness, is simultaneously an analysis of methods. In the final section of this chapter, I want to look at a number of potential criticisms of a primarily formalist approach in the methods of drawing and visualization from the perspectives of the sciences and the arts. Initially, we might simply assume that drawing, dealing in static images, allows us to reinforce the 'retrograde movement of truth.' The emphasis on form (the leaf, the vertebrate skeleton) encourages us to overlook the processes of development. Our descriptions are inadequate to growth whenever they settle on any particular state and declare that state either the origin or the *telos* of that organism's development. Are there possibilities contained in drawing, time-lapse photography, and animation that complicate the assessments of their hidden mechanisms (as both Bergson and Canguilhem identify)? Can we focus instead on what we might call a phenomenological relation or, as Whitehead would put it, a prehensive relation, between the artist and her work?

3. Drawing lived time

Scottish biologist and mathematician, D'Arcy Wentworth Thompson, in his book *On Growth and Form* (1917) explores a number of the problems broached so far, namely, the articulation of the interactions between internal and external selective forces, through a consideration of the relation between microscopic and macroscopic processes, and the use of explanatory principles between the extremes of teleology and physical reductionism. This final section will also serve as an outlook onto the next chapter on the potential of speculative methods in drawing and diagram-making as a way of exploring the methodological links between physics and metaphysics.

Thompson advocates morphology, the close study of living forms, grounded in Goethe's botanical studies, as a way of demonstrating the strict conformity of processes of growth and development in living things to physical laws, starting from their rudimentary formation in embryogenesis. The interactions of form and growth, being mathematical problems in the former case, and physical problems in the latter, mean that 'the morphologist is, *ipso facto*, a student of physical science.' (Thompson 2016, p. 8) The book *On Growth and Form* deploys extensive examples and diagrams to demonstrate this fundamental feature of life, but it is also an invaluable meditation on the methods of the morphologist, and of the utility of visualization for working out conceptual problems more broadly. As with the formalism of Goethe, the priority given to form by no means ignores or obscures the dynamics of growth. We have already seen through Goethe's attempts to articulate the processes of metamorphosis and the spiral tendency that the identification of some sort of 'Protean' form necessitates a subtle account of the ways in which open-ended processes or tendencies of growth are 'reigned in' and shaped by internal and external physical determinants. The task of the morphologist is not to 'freeze' processes in their tracks, and thereby succumb to Bergson's cinematographical illusion, but rather to study the 'action of forces' that have produced changes in form over the course of an organism's life (or indeed of any non-living object). As Thompson underlines:

> The form of an object is a 'diagram of forces', in this sense, at least, that from it we can judge of or deduce the forces that are acting or have acted upon it: in this strict and particular sense, it is a diagram, –in the case of a solid, of the forces that *have* been impressed upon it when its conformation was produced, together with those that enable it to retain its conformation; in the case of a liquid (or of a gas) of the forces that are for the moment acting on it to restrain or balance its own inherent mobility. (Thompson 2016, pp. 11-12)

Expanding this formal principle to a living organism then incorporates both a *kinetics* of its physiological development and degradation and a *statics* or 'balance of forces' that allows it a certain degree of equilibrium (or relative permanence). The search for the *effects* of forces, in the absence of direct evidence of the nature of those forces (that, historically, might have been attributed to some Prime Mover or to a vital or animating principle), echoes Bergson's references to an *élan vital* in *Creative Evolution*, insofar as it is an epistemological and methodological claim about the limitations of conceptual knowledge. Thompson criticizes 'the common language of books,' within the realms of embryology and evolutionary theory that focuses excessively, in his view, on the 'material elements' that trigger change, for overlooking the effects of the *dynamics* of development. (Thompson, p. 14) Predating the discovery of the structure of DNA, Thompson's perspective promotes a study of the interplay of forces and its effects on individual parts of an organism before the biological sciences' increased preoccupation with the detail of the genetic composition of an organism:

> Matter of itself has no power to do, to make, or to become: it is in energy that all these potentialities reside, energy invisibly associated with the material system, and in interaction with the energies of the surrounding universe. (Thompson 2016, p. 160)

Later complemented by Schrödinger's explanation of the connection between atomic and molecular phenomena, Thompson examines the differing effects of scale on organic development. The difference between the behaviour of a ripple in a body of water and that of a large wave illustrates this contrast in effects between molecular and molar forces, an observation of effects that can then be applied to living organisms. Here, smaller forms tend to arise in conformity with surface-tension, hence the recurrence of spherical forms in micro-organisms, whilst larger forms are more subject to the effects of gravity. (Thompson 2016, p. 33)

What, then, is the relationship between form and growth? What are these molecular or microscopic forces, and how can we discern them mathematically and diagrammatically, according to Thompson? As he explains, any magnitude by itself can be represented by a number or by a line of definite length. Changes in magnitude (in space only or time only) can be represented by a line of varying length. This is called a vector. Changes in magnitude, if rendered in spatial terms, can be represented by two lines, for example, one denoting length, and the other breadth. The resulting picture or drawing of the object is, then, a 'plane projection' of that object. We can thus define form as a 'ratio of magnitudes.' (Thompson 2016, p. 50) Furthermore, when variations in magnitude are mapped against successive moments in time, then this represents the object's 'growth,' and when we plot length (representing magnitude) against time, the resulting two-dimensional diagram gives us a 'curve of growth,' that is, it indicates the *velocity* or rate of growth. (Thompson 2016, p. 51) The accumulation of such data then helps to build up a more sophisticated visualization, albeit an abstract one, of the development of the chosen object, such as a developing embryo. Specifically, the superimposition of 'plane projections' of the developing organism over time yields 'a three-dimensional diagram which is a partial representation (limited to two dimensions of *space*) of the organism's gradual change of form or course of development.' (Thompson 2016, p. 51) Thompson argues that this intimate correlation between form and growth demonstrates that the study of organic development, understood in terms of rates of growth, or velocities, ought to be a prerequisite for the study of form. (Thompson 2016, p. 51)

The physical determinants of the changes in form differ according to the relative size and complexity of the organism, a problem that Thompson answers in a criticism of a passage in Darwin's *Origin of Species.* Darwin's difficulty in mapping the potential dynamics of use and disuse onto variations in species of birds with a common ancestor lies in the phenomenon of the great resemblance between the foetuses of each species, whereas the forms of the adults differ greatly. Thompson counters Darwin's suggestion that selection (determined by use or disuse) tends to be enacted upon the adult members of a species. Instead, he reiterates the difference between physical effects on smaller forms and those that occur on the greater magnitudes involved when dealing with individuals in later stages of life. In short, the developmental changes in an embryo are more greatly determined by general molecular forces, whilst the changes in later stages are increasingly idiosyncratic as the individual grows in size and form. Such an insight, Thompson notes, refers us back to the phenomenon of recapitulation, favoured, as we saw, by Haeckel. If ontogeny recapitulates phylogeny, it is because early developmental processes are shaped within common physical constraints.

How are the actions of 'molecular forces' demonstrated, such that they help to explain what might otherwise seem to be the emergence of highly improbable structures? Thompson cites a number of examples and cases that utilize analogues of life in an effort to minimize the explanatory burden of the biologist, such as the comparison of 'caryokinesis' (the division of a cell's nucleus in the process of mitosis) with a bipolar electrical field. A simpler, and immediate visual analogue of this aspect of mitosis is also found in diffusion experiments using ink and salt water, so configured as to mimic to a remarkable degree the coalescence of chromosomes between the two parts of the just-divided nucleus. Such demonstrations reinforce the insight that strictly non-living physical forces are at play in the most fundamental of living processes. As Thompson continues, the cell is best described as 'a "sphere of action" of more or less localised forces; and of these, surface-tension is especially responsible for giving to the cell its outline and its morphological individuality.' (Thompson 2016, p. 197) No particular part of the cell is identifiable as living as opposed to its non-living parts, since it is only in the interaction of the parts that energy-transfer takes place. Accordingly, the differentiating terms 'nucleus' and 'cell' should only be used 'in topographical expressions denoting two differentiated areas in a common structural basis.' (Thompson 2016, p. 198) This characterization of the cell presents us not with a material continuity but rather 'a continuity of forces, a comprehensive field of force, which runs through and through the entire organism and is by no means restricted in its passage to a protoplasmic continuum.' (Thompson 2016, p. 200)

We saw how Darwin, in *The Origin of Species*, marvelled at the mathematical precision displayed in the honey bee's construction of complex honeycombs. (Darwin 1996, p. 183) Thompson explains that it is not an innate craft of the bee, but a much more rudimentary process involving the interaction of the bee's instinctive work with the physical principles of surface-tension and the tendency towards equilibrium:

> …the walls assume their configuration when in a semi-fluid state, while the papery pulp is still liquid, or while the wax is warm under the high temperature of the crowded hive. Under these circumstances, the direct efforts of the wasp or bee may be supposed to be limited to the making of a tubular cell, as thin as the nature of the material permits, and packing these little cells as close as possible together. It is then easily conceivable that the symmetrical tensions of the adjacent films (though somewhat retarded by viscosity) should suffice to bring the whole system into equilibrium, that is to say into the precise configuration which the comb actually presents. (Thompson 2016, p. 333)

The deceptively complex construction of 'Maraldi pyramids' by the bee is attributable to the same forces that result in the facets of a rhombic dodecahedron to be found in a collection of soap bubbles or in the complex of uniform cells in plant stems and leaves. The structures in the former case can be explained in the same way as those in the latter.

Thus, the particular configurations of living cells tending towards spherical form, the complex processes of mitotic division, and the recurrence of certain geometrical forms across all orders of life are explicable in terms of a purely physical consideration of the interactions of form and growth. As we saw in the last chapter, Prigogine's later experiments in the production of dissipative structures would carry forward this intuition about emergent properties. What Thompson's analysis achieves is a potential simplification of certain problems within evolutionary and developmental biology. If the early stages of embryonic development can be explained with reference to basic physical principles, then this simplicity can minimize the need for overly speculative explanations for the emergence of more complex structures in adult forms and the ecological relationships between different species. Thompson's recourse to morphological study, mathematical models, and diagrammatizing demonstrates an intricate relation between the processes of observation, imaging, and problem-solving, and yet as contemporary British artist Gemma Anderson notes, 'morphological analysis as a taxonomic tool has been eclipsed by DNA and genomic analysis' resulting in a decline in the practice of the observational drawing of specimens. (Anderson 2014, p. 233)

Anderson's work in collaboration with a number of scientists (as well as, most recently, with philosopher of biology, John Dupré), has explored the value of morphological drawing as a way of addressing this increasingly under-utilized practice within zoological taxonomy. The practice of morphology should be seen, Anderson claims, as an invaluable tool both pedagogically and professionally for scientists and artists alike. (Anderson 2014, p. 233) As we saw in the previous chapter, the increasing focus on DNA analysis, using ever more sophisticated tools such as the electron scanning microscope, as well as the increased focus on statistical models of biological functioning, attesting to a sharpening of a broadening range of scientific specialisms, have been noted by Mayr, Margulis, and Lovelock alike, as detrimental to the depth of scientific discovery. Scientists working on different sub-disciplines are becoming less able to communicate and compare results with one another, whilst Anderson speaks of a much more local phenomenon of alienation experienced by the individual whose taxonomical work relies upon DNA sequencing, in place of observation of the specimen in question:

> it is not uncommon for molecular biologists to consider only the molecular data without any other knowledge of the species. Quentin D. Wheeler identifies this disconnection as a problem: "Much data may be collected but what is lost is the greater understanding of what those data mean or don't mean" (Anderson, 2014, p. 237)

Anderson's initial study of the value of drawing, 'an intimate, devotional act of wonder at the many forms and puzzles that species present' (Anderson 2014, p. 239), points to the power that it has, *and the time that it takes*, to provoke new realizations about the specimen being studied. There is a quality that is unique to the *act* of drawing that enables thought to articulate itself along lines not accessible through conventional signs (be they geometrical, diagrammatical, or linguistic). The development of the potential of this view of 'drawing as a way of thinking' in what Anderson coins 'Isomorphology' points to some potentially intriguing lines of research for the philosopher as well as for the artist and scientist. Whilst Anderson's most recent collaborations have involved the work of John Dupré, the focus has been on the interactions between the practices of scientists and artists, with, it seems, the theoretical scaffolding provided by the philosophy of science. In line with the broader explorations of the present book, I am interested in Anderson's work for its implications for how we work in philosophy itself. A first step to thinking about this is the project of Isomorphology which is 'the study of the shared forms and symmetries of animal, mineral and vegetable species through drawing practice.' (Anderson 2016, p. 10) The practice incorporates a kind of 'classificatory pluralism' (a term Anderson borrows from Dupré) that liberates taxonomy from adherence to fixed lines of demarcation between species, and indeed kingdoms, and ultimately non-living physical kinds. Anderson stresses the potential that such an approach might have for provoking new lines of enquiry in the work of classification, unfettered as it is by conventional specific and formal boundaries. Crucially, 'Isomorphology' is

> a blending of scientific and artistic experimentation which brings with it new modes of seeing and classifying the natural world. By placing the making of observational drawings at the foundation of this artistic experimentation, Isomorphology demonstrates drawing's continued viability as an epistemic process and as a way of producing knowledge. (Anderson 2016, p. 11)

The development of Anderson's work in collaboration with both mathematicians and biologists offers some conclusions about the potential applications of an approach centred on the act of drawing to philosophical enquiry itself. A clue to the approach we might take can be found in Anderson's work with mathematicians to develop a 'visual vocabulary' for presenting imaginary objects that exist only in the combinations between geometrical formulae and the minds' eyes of the mathematicians attempting to articulate them. Whilst the approach to theorizing the relationship between the practices of thinking and drawing is manifestly dualistic, being founded on the activities of the 'The Thinker' and 'The Drawer,' the resulting artworks speak to a more continuous and evolving relationship between the two conventionally distinct practices of mathematics and art:

> we focus on the drawing of imaginary objects— that is, objects that we see with our mind's eye. Whether the drawn object be physical or imaginary, all drawing is a sort of inverse vision [4]. By drawing with pencil on paper we give physical form to our mental images, and in the process we learn to see them better. Thus, in this context, drawing is a tool to train ourselves to see imaginary things better. (Anderson et al, 2015, p. 440)[4]

Anderson reiterates the value of the act of drawing as a pedagogical and creative process, rather than as a by-product of work that is to be ultimately translated back into abstract formulae:

> In each case, the process of drawing and the reflection that accompanies it transforms the drawer, changing the way in which they know and understand the object that is being drawn. This explains why drawing is so much more effective in this context than the use of computerbased visualization software: It is the act and experience of drawing itself that creates intuitive understanding. (Anderson et al, 2015, pp. 441-442)

In her book, *Drawing as a Way of Knowing in Art and Science* (first published in 2017), Anderson reflects on the transformation of her own practice towards what she names 'Isomorphogenesis,' which is intended as an amalgamation of D'Arcy Thomson's 'grid transformations,' the use of colour gradation by Paul Klee, and FormSynth, the computer-modelling system developed by William Latham. (Anderson 2019, p. 189). Anderson argues that Paul Klee's practice and artworks can be read as a kind of morphology, inspired by Goethe's methodology, and developing its own visualization of objects-in-process, in particular his use of gradations of colour (using layers of watercolour paint) to signify the passage of forms through a developmental sequence. (Anderson 2019, p. 144) Combining some speculative work on the possibility of rendering three-dimensional objects in four or more dimensions with her readings of Goethe, Klee, and Thompson, Anderson's method of Isomorphogenesis proposes 'a kind of drawing algorithm involving drawing actions (verbs) performed on a set of primitive shapes rather than from observation. The algorithm simulates possible analogs of developmental series based on principles similar to those that regulate plant and animal growth.' (Anderson 2019, p. 176)

The later application of this approach to the visualization of mitotic processes is, again, promoted on the basis of its value 'both in communicating the dynamic nature of biological processes and in generating new insights and hypotheses that can be tested by artists and scientists.' (Anderson et al 2019, p. 1) Anderson's work here in particular recalls D'Arcy Thompson's identification of forms as 'diagrams of forces' and develops the morphological attempt to articulate the interaction between form and growth in the developing organism. Anderson's drawings of the *process* of mitosis as a continuous set of changes in a single image, rather than a succession of images as snapshots of stages of the process, effectively combine the mathematical plotting of velocity, as explained by Thompson above, and the non-living chemical analogues of mitosis (the experiments in artificial caryokinesis) that mimic the appearance of mitotic division, as a means of reflecting on the physical dynamics that subtend the living process. The effort to visualize a process will never capture the true dynamic of the whole, but it can carry thought some way closer to an appreciation of its complexity. A widening of Anderson's approach to incorporate the working methods of philosophers would be an intriguing extension of this project.

References

Anderson, Gemma. 2014. Endangered: A Study of Morphological Drawing in Zoological Taxonomy. *Leonardo* 47, no. 53. doI:10.1162/LEON_a_00675

Anderson, Gemma. 2016. Drawing Resemblance: Mineral Nicknames and Isomorphology. *Architectural Theory Review*. doI:10.1080/13264826.2016.1177102

Anderson, Gemma. 2019. *Drawing as a Way of Knowing in Art and Science.* Bristol: Intellect.

Anderson, Gemma, Dorothy Buck, Tom Coates, and Alessio Corti. 2015. Drawing in Mathematics: From Inverse Vision to the Liberation of Form. *Leonardo* 48, no. 5. doI:10.1162/LEON_a_00909

Anderson, Gemma, John Dupré, and James D. Wakefield. 2019. Drawing and the dynamic nature of living systems. *eLife* 8. doI:10.7554/eLife.46962

Barnes, Jonathan. 2001. *Early Greek Philosophy*. London: Penguin.

Bergson, Henri. 1992. *The Creative Mind: An Introduction to Metaphysics*. Trans. Mabelle L. Andison. New York: Citadel Press.

Bergson, Henri. 1998. *Creative Evolution*. Trans. Arthur Mitchell. New York: Dover.

Canguilhem, Georges. 2008. *Knowledge of Life*. Trans. Stefanos Geroulanos and Daniela Ginsburg. New York: Fordham University Press.

Darwin, Charles. 1996. *The Origin of Species.* Oxford: Oxford University Press.

Deleuze, Gilles, and Félix Guattari. 1994. *What is Philosophy?*. Trans. Graham Burchill and Hugh Tomlinson. London: Verso.

Esposito, Maurizio. 2014. Problematic 'Idiosyncrasies': Rediscovering the Historical Context of D'Arcy Wentworth Thompson's Science of Form. Science in Context. 27 (1), 79-107. doI:10.1017/S0269889713000392

Goethe, Johann Wolfgang. 1989. *Goethe's Botanical Writings*. Trans. Bertha Mueller. Woodbridge, CT: Ox Bow Press.

Gould, Stephen Jay. 1977. *Ontogeny and Phylogeny*. Cambridge, MA: Harvard University Press.

Khandker, Wahida. 2014. *Philosophy, Animality and the Life Sciences.* Edinburgh: Edinburgh University Press.

Lovejoy, Arthur O. 1964. *The Great Chain of Being: A Study of the History of an Idea.* Cambridge, MA: Harvard University Press.

Mainberger, Sabine. 2010. 'In the vortex of the spiral tendency' - Questions of aesthetics, literature and natural sciences in the work of Goethe. *Estudos Avançados* 24 (69): 203-218.

Richards, Robert J. The tragic sense of Ernst Haeckel: his scientific and artistic struggles. *Darwin: Art and the Search for Origins* (2009): 92-125.

Sisko, J. E. 2010. Anaxagoras on Matter, Motion, and Multiple Worlds. *Philosophy Compass*, 5: 443-454. doi:10.1111/j.1747-9991.2010.00313.x

Stengers, Isabelle. 2011. *Thinking with Whitehead: A free and wild creation of concepts.* Trans. Michael Chase. Cambridge, MA: Harvard University Press.

Thompson, D'Arcy Wentworth. 2016. *On Growth and Form.* Stellar Editions.