Introducing organisms

Between unificationism and exceptionalism

Take a pinch (a gram) of good rich soil in the hollow of your hand; you may be holding half a billion organisms (Evans 2013). Add a drop of seawater (about 1 ml): you have probably enriched the ark in your palm by a million more (Becker 2013).[1] Not the most rigorous of surveys, perhaps, but any more systematic investigation would surely reinforce the same conclusion: the biosphere doesn't just *have* organisms, it is teeming with them. Organisms exist in a bewildering array of forms. Size alone hints at the scale of life's diversity; the mass of the largest organisms may exceed that of the smallest by over forty orders of magnitude.[2] The range of organisms' life activities is even more mind-boggling: they fly, they swim, they glow, they band together, they go it alone, they fix energy from sunlight, they live inside rocks and in deep-sea sulfur vents, they have contrived ways of surviving the most extreme and inhospitable places. Entire microbial ecosystems have just been discovered under the Antarctic ice (Christner et al. 2014). Moreover, these forms and activities exhibit a feature unique in the natural world; organisms are exquisitely suited to their conditions of existence. They are highly complex stable, adaptive, purposive systems. In the pursuit of their goals organisms possess a prodigious array of capacities. They are self-reproducing, self-building entities. They manufacture the very materials out of which they are constructed. These structures, these activities, this diversity, set organisms apart in the natural world. Organisms are natural entities to be sure, but they are no run-of-the-mill material things.

It isn't surprising, then, that organisms, their structures and activities, should demarcate a major scientific enterprise. Biology is the collection of disciplines dedicated to the study of living entities and their processes. There is hardly a

[1] You may also have killed a few.
[2] Blue whales (*Balaenoptera musculous*) may have a mass of 160,000 kg (NOAA Fisheries) while mycoplasma may be as little as 10^{-35} grams (Willmer, Stome and Johnston 2005). The General Sherman tree, *Sequioadendron giganteum*, in California is thought to have a mass of 560,000 kg (*Encyclopaedia Britannica* 2013). The fungus *Amillaria bulosa* may have a mass of 10,000 kg (Smith et al. 1992).

more vibrant intellectual endeavour in the world today. But modern biology embodies a conundrum.

The core of modern biology is the theory of evolution. It ranks among the most powerful, well-corroborated scientific theories ever devised. Its objective *inter alia* is to explain the fit, function and diversity of organisms (Lewontin 1978). Yet, the category *organism* has very little role to play in evolutionary theory. Nowadays, evolutionary theory principally deals in the dynamics of supra-organismal assemblages (populations) of suborganismal entities (genes). The distinctive properties that make organisms organisms play virtually no part in the explanation of evolutionary phenomena, or at least that version of evolutionary theory that has grown to such prominence throughout the twentieth century.

Perhaps this observation is too banal, too familiar, to raise any concern, but it is at least counterintuitive that the special properties that mark out a domain of scientific enquiry shouldn't have a place in the theoretical apparatus of that science. It would be decidedly odd, for instance, were the properties that make physical entities physical, or chemical entities chemical, or psychological entities psychological, not to figure in our theories of physics, chemistry and psychology. So, the absence of organisms from evolutionary theory ought to engender at least some mild curiosity.

It hasn't gone unnoticed, of course.

> Something very interesting has happened to biology in recent years. Organisms have disappeared as the fundamental unit of life. In their place we now have genes, which have taken over all the basic properties that used to characterize living organisms. (Goodwin 1994:1)

But there isn't a whole lot of angsting about it either. Evolutionary biologists have tended to be rather sanguine about the incidental role of organisms: 'The organism is only DNA's way of making more DNA' (Wilson 1980: 3). Evolution, nowadays, is a molecular or genetical phenomenon.

> Evolution is the external and visible manifestation of the survival of alternative replicators. . . Genes are replicators; organisms. . . are best not regarded as replicators; they are vehicles in which replicators travel about. Replicator selection is the process by which some replicators survive at the expense of others. (Dawkins 1976, 82)

Our objective here is to ask two questions about the place of organisms in evolutionary biology. The first is: 'Where did they go?' alternatively, 'Why have organisms been marginalised in evolutionary thinking?' The second is: 'Where should *we* go?' or 'in what ways, if at all, would our understanding of evolution be altered were organisms to figure more prominently?' In Part I, I survey some of the reasons for the marginalisation of organisms in twentieth-century evolution. In Part II, I canvass some reasons for reassessing this dis-organicised evolution. In Part III, I offer a rather programmatic, speculative attempt at a conception of evolution in which the distinctive capacities of organisms are pivotal. There is a prior question, of course; 'What *is it* about organisms that should have prompted this issue in the first place?'

I.1 Life's paradox

Dublin February 3, 1943. The Great Lecture Hall of Trinity College Dublin is buzzing with anticipation.[3] The first of three public lectures is about to be delivered by the newly appointed director of Trinity's School of Theoretical Physics. The speaker is the Nobel laureate physicist Erwin Schrödinger. Schrödinger's chosen topic may well strike the assembled audience as somewhat misplaced. He proposes to address the question *'What is life?'* Why should a physicist of such renown feel impelled to poach on biologists' preserve? As a pioneer of quantum mechanics, Schrödinger's illustrious reputation was forged through his imaginative engagement with some of the most perplexing problems of physics: wave mechanics, entanglement, nonlocality and that cat! Surely there was enough in the dynamic new physics to thrill and edify his expectant audience, without descending into the murky waters of biology. Most certainly there was, but it was the very dynamism of physics in the preceding half-century that underscored the urgency of Schrödinger's question. While the physics of Schrödinger's day had met with unprecedented success in revealing the fundamental laws that govern the world, those laws seemed to proscribe the very existence of living things.[4] How could life exist at all, let alone in its prodigious abundance, in contravention of the dictates of physics? What should the sciences do about organisms?

One strategy might be to adopt what we could call 'biological exceptionalism': biological phenomena are set apart as fundamentally different from the nonliving phenomena of the world. Organisms are unique, and we should acknowledge that their singularity earns them a special place in the sciences. There is no reason to suppose that they should be subject to mere physical law. Exceptionalism would certainly accommodate Schrödinger's observation that the laws of physics appear not to govern the behaviours of living things.

The idea of a law of nature seems to be a metaphorical extension of the juridical notion. Scientific laws, like their administrative counterparts, govern the behaviour of entities in their own proprietary domains. In Schrödinger's adopted institution, Trinity College Dublin, college law permits a student to order a glass of wine during an exam, but only if he is wearing his sword.[5] In

[3] The occasion is vividly depicted in Schneider and Sagan (2007).
[4] I'll say a little more about just how the laws of nature might have appeared to legislate against organisms below.
[5] It's always a 'he'.

Toronto, to cite another example, it is illegal to drag a dead horse down the street on a Sunday.[6] These rather parochial laws have no remit beyond their limited jurisdiction. Students at Trinity's rival institution, University College Dublin, are not similarly empowered to order wine during their exams. Nor does the stricture against hauling carcasses apply in, say, Calgary.[7]

Just as there are laws that apply only to Trinity and Toronto, there might be laws that hold only within specific scientific domains and not beyond. The laws of economics and psychology, if any such there be, evidently don't govern the behaviour of all living things, much less nonliving things. Perhaps the laws of physics no more govern behaviour in the biological realm than the by-laws of Toronto govern the behaviour of Calgarians. Biological exceptionalism suggests that the paradox of life that so perplexes Schrödinger may be a simple consequence of naively overgeneralising the laws of physics.

Exceptionalism of this sort would have been anathema to a physicist such as Schrödinger. Indeed, it would not at all sit easily with the vast majority of contemporary scientists and philosophers. The reason is that biological exceptionalism risks misrepresenting the relation between biology and physics. The respective domains of biology and physics may be distinct, but they are not disjoint. The laws of physics apply to all natural phenomena, including living things and biological process. The distinctive features and capacities of biological entities must be reconciled with the laws of physics.

We might call the alternative prompted by this line of thought 'unificationism' in contradistinction to exceptionalism. Unificationism, for its part, seems to honour a deep-lying modern commitment to the fundamental place of physics in the study of the natural world. But it has its downsides too. In particular, it fails to do justice to the very intuitions that motivate exceptionalism – *viz.* that biological phenomena are uniquely, and strangely different.

So, the dilemma raised by the paradox of life is how to understand organisms as, on the one hand, the highly aberrant distinctive entities they are, and on the other, mere physical things like anything else. Neither exceptionalism nor unificationism seems wholly satisfactory, yet each seems to capture a feature of the biological world that eludes the other. This is the paradox that Schrödinger's *What is Life?* addresses. As we shall see, the resolution he offers is highly original, enormously fertile and frustratingly ambiguous. But first it is worth noting that the dilemma Schrödinger addresses is as old as biology itself.

[6] Trinity: https://mligroup.wordpress.com/tag/trinity-college-dublin/; Toronto: http://www.lufa.ca/news/news_item.asp?NewsID=7235

[7] Indeed there's little else to do there on a Sunday.

I.2 Exceptionalism and unificationism

The problem of reconciling the naturalness of organisms with their peculiarity is an enduring challenge to the sciences. Indeed, an exceptionalist/unificiationist dialectic runs throughout the entire history of comparative biology.

I.2.1 Psuche

Aristotle, as Marjorie Grene (1974) was fond of saying, was the one great philosopher who was also a great biologist. Aristotle's extensive biological works set out to taxonomise and explain the startling array of biological forms, and their unique abilities to make their way in their respective conditions of existence. Aristotle is probably best considered an exceptionalist; his biological works emphasise the uniqueness of organisms. Each organism, Aristotle surmised, has a 'soul' (*psuche*). *Psuche* is nothing like the notion of soul as it appears in the Abrahamic religions; it is a theoretical posit, a wholly natural principle of organisation distinctive of organisms. In his principal work on the nature of life and mind, *de Anima*, Aristotle (1995) tells us that *Psuche* consists in an organism's goal-directed capacity to organise the matter at its disposal into a well-functioning organism typical of its kind.

> Soul (*psuche*) is distinguished by a set of vital functions, nutrition, growth, locomotion and (in the case of humans) cognition. We may think of the form of an organism as a set of organizing principles, or a set of goal-directed dispositions, to organize its matter in such a way that the organism is capable of performing particular soul functions (in the particular way) distinctive of its kind. (Lennox 2001: 183)

The leading idea in Aristotle's biology is that the organism is a finely tuned functioning unit, whose parts and activities conjointly subserve the organism's '*way of life*'. The Aristotelian term is '*βιος*' (Lennox 2010). *βιος* consists in '. . . the full complement of an animal's activities organised around the single goal of its specific way of life' (Lennox 2009: 355). Each organism is imbued with a capacity to build and regulate itself in such a way that equips it to succeed in its distinctive manner. The world is replete with highly organised entities pursuing different, but related, ways of life.

Aristotle's biology is formulated in explicit opposition to that of the Pre-Socratic Atomists. The Pre-Socratic Atomists, like Democritus and Empedocles, are early exemplars of unificationism. The cosmos, according to the Atomists began in chaos, atoms moving randomly in the void. Some atoms chanced to encounter one another and combine. Some combinations were ephemeral, but some were stable and persisted. These aggregations of atoms give us our macroscopic, enduring entities, including organisms. The properties of any complex entity are simply the result of the causal, mechanical interactions of its parts. The entire edifice of the world is the consequence of chance encounters of randomly moving atoms, and the necessary consequences of their interactions.

Empedocles even posited an atomistic theory of the function and diversity of biological form that bears a passing resemblance to the modern theory of natural selection. Suborganismal parts were first formed by the agglomeration of earth. These disembodied parts – limbs, heads and the like – wandered the world aimlessly. Occasionally, under the guiding power of 'love' these parts aggregated together to form organisms. But, 'the power of love is a curious thing'; it makes for some mismatched partnerships. There were ox-headed men, and men-headed oxen. That all sounds arcane, and distinctly uncontemporary, until we ask why we no longer see such strange monstrosities. According to Empedocles, those collections of suborganismal parts that collaborated in making up well-functioning organisms survived; those that worked less well together perished.[8] For Pre-Socratic Atomists, then, organisms are mere congeries of their suborganismal parts. An organism's way of life is just the result of the mechanical interactions of its randomly aggregated pieces.

Aristotle insisted, against this picture of life as the consequence of random aggregations, that the chance encounters and mechanical interactions of an organism's parts are insufficient to explain the range and diversity of biological form. In fact, the Atomist attempt to explain an organism's way of life in terms of the arrangements of its parts inverts the proper explanatory order. For Aristotle, way of life explains the arrangement of parts and not the other way around. The co-ordination and integration of an organism's various parts is in no way haphazard. They are put there by the organism itself to subserve the organism's particular way of life. To suppose that these arrangements are merely matters of chance is to ignore some strikingly robust natural regularities.

What Aristotle means by this is that while any particular kind of organism may seem extremely improbable, it is also remarkably regular. Consider the extravagant 'sea slug' nudibranch *Pteraeolidia ianthina*.[9] These are bizarre, flambouyantly – almost psychedelically – coloured marine organisms that frequent the warm waters of the Indo West Pacific. They are a magnificent sight. Their iridescent blue cerata are striking, but they are not just for show. They house bioluminescent zooaxanthelae that fix energy from light, and provide nourishment for the nudibranch, enabling it to survive extended periods of time without eating – furbelow meets function. One might suspect that such a conspicuous creature would be easy prey. *P. ianthina* has a further

[8] Roux (2005) remarks: 'The account of the origin of species by Empedocles is the first recorded account of the theory of natural selection' (p. 6).
[9] The beast whose portrait graces the cover of this book.

contrivance to prevent itself from being eaten. It ingests the venomous spicules of sea anemones, which then pass through the slug and lodge in its mantle. The poison protects the nudibranchs from predators. This seems like a highly 'unlikely' – indeed outlandish – arrangement of form and function, and yet *P. ianthina* occurs reliably over and over again. The high fidelity reproduction of organisms capable of effectively pursuing the way of life typical of their kind, no matter how bizarre, is a robust regularity. Through their development and reproduction the same 'unlikely' forms occur over and over again, with the sort of predictability that we associate with truly law-governed phenomena, and not mere chance occurrences (Sorabji 1990). The regular occurrence of such highly integrated, exquisitely functional structures in organisms could not happen spontaneously (Johnson 2005). These regularities need to be explained, but to label them as mere chance, Aristotle believes, is to decline to do so.[10]

Aristotle asserts that some regularities in the world occur because they subserve purposes or goals. Systems that have goals or purposes reliably bring about states of affairs that are conducive to the fulfilment of those goals or purposes, however 'unlikely' they might have been. This is a very familiar way of predicting and explaining certain kinds of regular occurrences. Notably, we understand rational agency in this way. We explain and predict the behaviours of a rational agent by identifying her goals and then describing the ways in which her activities contribute to the fulfilment of those goals.

Where natural entities pursue goals or purposes, we can explain their behaviour and their structure by appeal to those purposes. Explanations that appeal to goals are called 'teleological'.[11] According to Aristotle, organisms are the very paradigm of purposive, goal-directed systems. The regular structures and activities of an organism, the intricate integration of its various parts, can all be explained by the fact that they are conducive to the pursuit of the organism's way of life. *Way of life* is a teleologically basic purpose of an organism, and it is what justifies teleological explanations and predictions of biological form and function in just the way that the goals of a rational agent underwrite the prediction and explanation of her actions. In representing organisms as entities that pursue purposes – ways of life – Aristotle is setting them apart from the rest of the natural world.

I.2.2 Modern mechanism

Aristotle's biology, ingenious as it might be, sounds a discordant note to the modern ear. The whole theoretical edifice has a thoroughly archaic cast. It

[10] I pursue the implications of this issue in more detail in Chapter 9.
[11] There are two recent superb extended discussion of Aristotle's teleology. They are Johnson (2005), and Leunissen (2010).

populates the natural world with forms, natures and purposes. Aristotelian science was anathema to those who forged the scientific revolution, from the arcane methods, to the esoteric metaphysics, to the biological exceptionalism. Indeed, it is often said that modern science was founded in explicit opposition to Aristotle. The scientists who initiated the Scientific Revolution – Copernicus, Galileo, Descartes, Gassendi, Boyle, Newton – sought to rid science of Aristotle's occult and obscurantist thinking.

The worldview that grew out of this revolution takes nature to be a machine.[12] We come to an understanding of the natural world in much the way that we learn about the workings of a machine. We take it apart (literally or conceptually) and investigate how the various parts fit together, and how the various interactions among the parts – pushing, pulling, bending, heating, repelling, attracting – aggregate to produce the activities of the complex whole. For half a century Descartes' physics provided the model for the study of the natural world, and the model of the natural world was the machine. 'I have described this earth, and indeed the whole universe, as if it were a machine: I have considered only the various shapes and movements of its parts' (Descartes 1647 [1985], §188).

Descartes' method of the machine applies just as much to his biology as to his physics. Organisms, for Descartes are *bêtes machines* – '*bêtes*' because, unlike humans, they are not possessed of a soul, a thinking substance; '*machines*' because their structure and function are entirely to be accounted for by the interactions of the parts.

> The number and the orderly arrangement of the nerves, veins, bones and other parts of an animal do not show that nature is insufficient to form them, provided you suppose that in everything nature acts in accordance with the laws of mechanics. (1639 [1985],§134)

Living or otherwise, machines are machines.

Descartes' mechanistic biology is much praised by his contemporaries, and highly influential. Philip Sloan (1977) cites the sixteenth-century Danish anatomist, Neil Stenson's, effusive endorsement of the power of Descartes' mechanism to reveal the mysteries of even human anatomy:

> Descartes . . . was the first who dared to explain all the functions of man, and especially of the brain, in a mechanical manner. Other authors describe man; Descartes puts before us merely a machine, but by means of this he very clearly exposed the ignorance of others who have treated of man, and opened up for us a way by which to investigate the use of the other parts of the body as no one has done before. (Quoted in Sloan 1977: 20)

[12] The methodology of mechanism is treated in more detail in Chapter 1.

Thus Descartes' conception of living things embodies a radical unificationism, set explicitly in opposition to the exceptionalism of the ancient and medieval study of organisms.[13]

I.2.3 Organisms as natural purposes

Despite Descartes' advocacy, many early modern biologists and philosophers were distinctly pessimistic about the capacity of the new science to subsume all the distinctive features of the biological world. One enduring problem for biologists was how to explain the development of an organism from its comparatively modest, undifferentiated single-celled zygote stage to the fully formed, complex highly differentiated, integrated adult. To many eighteenth-century biologists, like Georges Comte de Buffon and Caspar Friedrich Wolff (*contra* Descartes' insistence), there seemed to be too little specific detail contained in a fertilised egg to allow one to 'deduce from that alone, . . ., the whole figure and conformation of its parts' (Wolff: quoted in McLaughlin 2014: 8). These biologists surmised that there must, then, be some extra 'epigenetic' factor, not contained within the fertilised egg, that directed the organism toward the development of its proper form. For some this 'penetrating force' or '*vis essentialis'* is a wholly biological, nonphysical feature of the world.

The philosopher Immanuel Kant's biology was strongly influenced by Buffon and Wolff (among others). He absorbed from Wolff the evident inability of mechanism to explain regularities of organismal development. He took from Buffon the idea that organisms are self-organising, self-synthesising entities. Yet, as a thoroughly modern scientific thinker, Kant was keenly aware of, and strongly supportive of, the modern, mechanical conception of science. He considered Newton's laws of motion to have limned the very nature of matter. Newton's laws tell us that matter is inert, non-self-moving. When it changes, it does so through the influence of external forces acting from outwith. Matter does not organise itself; it does not replicate itself. But organisms do all these things. If Newton's laws lay down the rules by which matter conducts itself, organisms flout them flagrantly. Kant expresses his pessimism that the methodology that revealed the secrets of physics should be so forthcoming with those of biology (Cornell 1983).

Kant makes much of the fact that organisms synthesise the materials out of which they are made (McLaughlin 2000). Consequently, an organism has the parts it has, in their particular arrangements, precisely because in its

[13] The machine analogy persists into contemporary biology (see, for example, Lewens 2004), where Nicholson complains, it '. . . fundamentally misrepresents the nature of the very subjects . . . it seeks to explain' (2014: 168–169). Talbot (2013) argues for the importance of the 'machine-organism' concept in generating the Modern Synthesis conception of the unit gene.

development the organism has made those parts and has put them there to serve its crucial vital functions:

> . . . an organism first processes the matter that it adds to itself into a specifically-distinct quality, which the mechanism of nature outside of it cannot provide, and develops itself further by means of a material which, in its composition, is its own product. (Kant 1790 [2000]: 371)

As a consequence, the relation between an organism and its parts is vastly different from the relation between a run-of-the mill machine and its parts. Like machines, organisms are the consequences of the interactions of the parts. But, unlike machines, an organism's parts are the consequence of the activities of the organism as a whole. The constituent parts and processes of a living thing are thus related to the organism as a whole by a kind of 'reciprocal causation'.

> I would provisionally say that a thing exists as a natural end if it is cause and effect of itself. (Kant 1790 [2000]: 371)

Organisms are thus crucially unlike machines, just as Buffon insists. They are self-building, self-regulating, highly integrated, functioning wholes, that exert a particularly distinctive influence over the capacities and activities of their parts.

> The essential definition Kant offered of . . . organic form . . . was that of the reciprocal interrelation of parts as means to ends, and consequently of the priority of the whole over the parts as means and ends, and consequently, of the priority of the whole over the parts in the constitution of the entity. (Zammito 1991: 218)

Kant's own definition of an organism emphasises the reciprocity between part and whole.

> The definition of an organic body is that it is a body, every part of which is there for the sake of the other (reciprocally as an end, and at the same time, means). . . . An organic (articulated) body is one in which each part, with its moving force, necessarily relates to the whole (to each part in its composition).[14]

Kant is simply highlighting the distinguishing property of organisms that we have already identified: their purposiveness. He tells us that purposiveness is essential to our concept of an organism. Moreover, an organism's purposes are immanent in it; they are not extrinsic purposes, like those of artefacts. Hence, organisms are natural purposes.

Their status as natural purposes puts organisms beyond the ambit of the methods of the modern sciences. The features and capacities of organisms just cannot be adequately accounted for by appeal to causes and laws (Ginsborg 2001). Thus while endorsing the modern conception of the scientific enterprise,

[14] *Opus postumum*, quoted in Guyer (2005: 104).