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Darwinism and mechanism: metaphor in science

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Abstract

There are two main senses of 'mechanism', both deriving from the metaphor of nature as a machine. One sense refers to contrivance or design, as in 'the plant's mechanism of attracting butterflies'. The other sense refers to cause or law process, as in 'the mechanism of heredity'. In his work on evolution, Charles Darwin showed that organisms are produced by a mechanism (natural selection) in the second sense, although he never used this language. He also discussed contrivance, where he did use the language of mechanism. This discussion relates metaphor in general and Darwin's use of the machine metaphor in particular to the problem of the nature of science, concluding that one use of the metaphor reinforces the objective nature of science and the other use reinforces the subjective nature of science.
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> **mechanism: 1** the structure or adaptation of parts of a machine. **2** the mode of operation of a process. (*Concise Oxford dictionary*)

The discovery of the mechanisms by which causes produce or generate their effects is a central part of a scientific investigation. The discoveries of the mechanism of chemical reactions, of the mechanism of inheritance, and so many more, are examples of the fulfillment of this search. But a word of caution is

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> needed here as to the meaning of 'mechanism'. In ordinary English this word has two distinct meanings. Sometimes it means mechanical contrivance, a device that works with rigid connections, like levers, the intermeshing teeth of gears, axles, and strings. Sometimes it means something much more general, namely any kind of connection through which causes are effective. . . . It is in this latter sense that the word is used in science generally, in such diverse expressions as the mechanism of the distribution of seeds and the mechanism of star formation. In hardly any of these cases is any mechanical contrivance being referred to. So we must firmly grasp the idea that not all mechanisms are mechanical. (Harré, 1972, p. 118)

1. Introduction

This is an essay about Charles Darwin, but my intent is philosophical rather than purely historical. I am interested in the nature of science. Is science a disinterested reflection of objective reality or is it a social construction, a subjective epiphenomenon on the culture of the day? In previous publications, in search for an answer to my question, I have focused on the nature and role of metaphor in science (Ruse, 1996, 1999, 2003). Basically, I have argued that metaphor is widely used and indispensable. Moreover, it points to a middle way between the objective and the subjective. Science is objective, inasmuch as it is structured and guided by epistemic factors or values. It is beyond the individual or purely cultural because it aims to be predictive, consistent with other knowledge claims, internally coherent, unificatory, simple. Yet science is in some way subjective, because we also structure and interpret it through our metaphors, things drawn from individual experience and the culture(s) within which science is produced. Nor are the metaphors readily eliminable, for—showing that in a sense the objective/subjective dichotomy collapses—they give rise to some of the crucial epistemic virtues of the best kind of science, the kind of science we most readily think of as objective. Most particularly, metaphor generates predictive fertility—or, as it is sometimes said, metaphor is the key factor behind the heuristic power of good theories. In this essay, I want to look at one of the most important and powerful metaphors in the history of science, the metaphor of 'nature is a machine'—the mechanism metaphor—to see what role (if any) it played in the thinking of Charles Darwin and subsequent evolutionists, and to find what if anything this discussion contributes to my philosophical concerns.

2. Nature is a machine

'Nature is a machine' is a metaphor that was introduced into science in the seventeenth century by people such as the French philosopher–scientist René Descartes (Ruse, 2002). This metaphor was rooted in the culture of the day, namely that we can think of the world as a creation of God, and what God created was an efficiently functioning machine rather than (say) a plant or alternatively a totally useless and

random mess. In other words, the metaphor was bound up with natural religion (the religion of reason, rather than revealed religion, the religion of faith). Metaphorically, one is thinking of the world as a machine, literally one is thinking of the world as a creation by God. As intimated by the quotations given at the head of this essay, the metaphor fragmented into two senses: the world as a whole as a machine and individual parts as mechanical contrivances. As is often the case with fertile mechanisms, this led to something of a tension generated by the metaphor itself—machines are entities that work according to unbroken law and at the same time they are entities with an end, a purpose.

At the general level (leading to definition **2** in the dictionary, to Harré's 'any kind of connection'), one starts to see the world as governed by unbroken law, regarding it as something like a clock, forever going in motions without end. The prime example of course is Newton's mechanics—provocative and pregnant term! This attitude (the 'mechanical philosophy') is marked by (in Aristotelian terms) an exclusive reliance on efficient (and perhaps formal and material) causes, and a rejection of final causes. The English physicist Robert Boyle is the definitive source here. Against the Aristotelian notion that somehow 'nature' itself has a being and a kind of mind or life force of its own, and making reference to a wonderful clock built (between 1571 and 1574) by the Swiss mathematician Cunradus Dasypodius, Boyle responded:

> And those things which the school philosophers ascribe to the agency of nature interposing according to emergencies, I ascribe to the wisdom of God in the first fabric of the universe; which he so admirably contrived that, if he but continue his ordinary and general concourse, there will be no necessity of extraordinary interpositions, which may reduce him to seem as if it were to play after-games—all those exigencies, upon whose account philosophers and physicians seem to have devised what they call nature, being foreseen and provided for in the first fabric of the world; so that mere matter, so ordered, shall in such and such conjunctures of circumstances, do all that philosophers ascribe on such occasions to their omniscient nature, without any knowledge of what it does, or acting otherwise than according to the catholic laws of motion. And methinks the different between their opinion of God's agency in the world, and that which I would propose, may be somewhat adumbrated by saying that they seem to imagine the world to be after the nature of a puppet, whose contrivance indeed may be very artificial, but yet is such that almost every particular motion the artificer is fain (by drawing sometimes one wire or string, sometimes another) to guide, and oftentimes overrule, the actions of the engine, whereas, according to us, it is like a rare clock, such as may be that at Strasbourg, where all things are so skillfully contrived that the engine being once set a-moving, all things proceed according to the artificer's first design, and the motions of the little statues that as such hours perform these or those motions do not require (like those of puppets) the peculiar interposing of the artificer or any intelligent agent employed by him, but perform their functions on particular occasions by virtue of the general and primitive contrivance of the whole engine. (Boyle, 1996, pp. 12–13)

As it happens, Boyle himself was God-obsessed. But was not his vision half-way to deism, to a being who set all in motion and who then stands back? Certainly, if you look at things with the advantage of hindsight, there is something to this. If you take soul out of the universe and substitute an unfeeling machine, you are indeed on the way to a godless creation—at least, to a creation that can be regarded as godless. Boyle himself was as much against deism as he was against Aristotelianism. He thought that God creates the universe and then holds it immanently in His hands. If He quits at any moment, then everything collapses. For this reason, Boyle was (unlike the deist) ready to accept miracles. God can (or did) do these just as He pleases, because He is involved all of the time. But, of course, the trouble begins when you start to find that that which you thought was miraculous is in fact something that obeys the rule of law, a possibility that Boyle fully recognized, even though he thought it a point in his favour and against the Aristotelians.

> And when I consider how many things that seem anomalies to us do frequently enough happen in the world, I think it is more consonant to the respect we owe to divine providence to conceive that, as God is a most free as well as a most wise agent, and may in many things have ends unknown to us, he very well foresaw and thought it fit that such seeming anomalies should come to pass, since he made them (as is evident in the eclipses of the sun and moon) the genuine consequences of the order he was pleased to settle in the world, by whose laws the grand agents in the universe were empowered and determined to act according to the respective natures he had given them; and the course of things was allowed to run on, though that would infer the happening of seeming anomalies and things really repugnant to the good or welfare of divers particular portions of the universe. (Ibid., p. 13)

Yes, all of this is no doubt true, but the fact is that, as a need of a God of miracles recedes, then the need of a God at all recedes. The world is clockwork and leave it at that.

For Boyle, it was at this point that the other (more specific) sense of the metaphor—parts of the world as mechanisms or contrivances (as Harré calls them, dictionary definition **1**)—started to kick in. One focuses here on the purpose or point of a machine. This really is a teleological notion, one that puts final cause up front. Unlike Francis Bacon and Descartes who thought that they could do science without final causes—vestal virgins, Bacon called them, pretty but sterile—Boyle realized that in the biological world they are necessary for full understanding. If the eye is not made for seeing, then absolutely nothing makes sense at all. Against the Frenchman and his followers, there is a positive moral obligation to study nature and to work out its adaptations. As Boyle wrote in another of his essays, the *Disquisition about the final causes of natural things*:

> For there are some things in nature so curiously contrived, and so exquisitely fitted for certain operations and uses, that it seems little less than blindness in him, that acknowledges, with the Cartesians, a most wise Author of things, not to conclude, that, though they may have been designed for other (and perhaps

> higher) uses, yet they were designed for this use. As he, that sees the admirable fabric of the coats, humours, and muscles of the eyes, and how excellently all the parts are adapted to the making up of an organ of vision, can scarce forbear to believe, that the Author of nature intended it should serve the animal to which it belongs, to see with. (Boyle, 1966 [1688], pp. 397–398)

Boyle continued that supposing that 'a man's eyes were made by chance, argues, that they need have no relation to a designing agent; and the use, that a man makes of them, may be either casual too, or at least may be an effect of his knowledge, not of nature's' (ibid., p. 398). But not only does this then take us away from the urge to dissect and to understand—how the eye 'is as exquisitely fitted to be an organ of sight, as the best artificer in the world could have framed a little engine, purposely and mainly designed for the use of seeing' (ibid.)—but it takes us away from the designing intelligence behind it.

Boyle did not see this position of his as something threatening to the mechanical position but as complementing it. He thought that the general sense of mechanism (world as machine, process) was complemented by and harmonized with the specific sense of mechanism (parts as contrivances). But one can see why people such as Bacon and Descartes—who theologically accepted final causes—wanted final causes out of science and were pushing towards a position of (what in today's terms) we might call methodological naturalism or mechanism, where the original concept of nature as a machine (the general sense) has become (what literary theorists call) a dead metaphor. As God gets further and further removed from science judged as science—and this has been the tendency since the seventeenth century—the very success of the metaphor of 'nature is a machine' has brought about its demise. As scientists, we no longer think of nature as created by an intelligence. And this being so, as Harré rather hints, this means that although we might continue to talk in terms of mechanism, at this level, we do not really mean it. We do mean something and we do mean something very important—that nature works according to unbroken law—but we do not mean that nature is machine-like in the sense of 'designed by an intelligence'.

At this point, you might be led to conclude that, with the general sense of the metaphor now gutted of its original force, for all that Boyle argued otherwise, the practice of science puts pressure on the scientists to downplay or eliminate the specific sense. If nature is a machine only in name, then it is anomalous—if not outright contradictory—to speak of parts as machine-like, as contrivances or specific mechanisms. By stressing the clockwork nature of the world in its own right without reference to purpose, you are undermining the intent of using the clock to tell the time. The act of referring to intent is (to use an evolutionary analogy) rather like having an appendix, perhaps useful once but no longer. Even more, like having some feature that was useful but now is positively harmful, such as (in Western countries) a fondness for sweet things. And if this is all so, then looking at things from a broader philosophical perspective, we surely have support for the position of the objectivists about science. They might agree that, in its earlier, immature stages, science is often if not always something much connected (primarily if not exclusively through metaphor) to the ways and norms of the society within which it is conceived. But

they will crow that, as the science matures, the epistemic norms take over and expel the cultural and societal (McMullin, 1983). And a mark of this is that the metaphors become less significant and active—either they become moribund, as is the case of the more general 'nature as machine', or they are expelled outright, as must or should have happened to 'organic parts are contrivances'. To quote the philosopher Jerry Fodor: 'When you actually start to do the science, the metaphors drop out and the statistics take over' (Fodor, 1996, p. 20). Although science starts in culture, when it matures it really is objective and culture free.

3. Darwin on mechanism

This somewhat lengthy prolegomenon now sets us up to think about Charles Darwin. In his masterwork, *On the origin of species*, Darwin established the fact of evolution and proposed a causal force, which today is taken as the key factor in change: natural selection. Surely, one might think, this is all going to fit very nicely and smoothly into the story just sketched above. Darwin strikes a key blow for the general 'nature as a machine' metaphor, because he is showing how organisms come into being as a result of the workings of blind, unguided law. His is the methodologically naturalistic theory *par excellence*, and in this sense natural selection is the apotheosis of what the modern scientist means by mechanism—'connection through which causes are effective'. But because he is so successful, Darwin is a major player in demoting or transforming this way of thinking into the status of dead metaphor. After Darwin, the world of organisms is no longer itself an organism (as the German idealists, the *Naturphilosophen*, would have argued) or a direct Creation (as natural theologians from Plato to William Paley would have argued) or a domain of vital forces (as Aristotle would have argued). It is just something that works by law, without final causes. And this being so, the other sense of mechanism, the specific sense, parts as contrivances, is doomed to oblivion. There are human–man mechanisms, of course—in Boyle's day clocks, in our day computers. But not in nature, and so we expect to find this kind of talk diminishing and ultimately vanishing.[1]

[1] I must acknowledge that there are those who argue that, far from adopting a mechanical view of the world, Darwin was deeply committed to an organicist picture of nature, being much indebted to the thinking of the German *Naturphilosophen.* This is the thesis of Robert J. Richards in his recent brilliant work, *The Romantic conception of life: Science and philosophy in the age of Goethe*. I think Richards is just plain wrong on this point. Since Richards and I have just aired our differences in public, I will refer the reader to this clash. Basically, although I agree with Richards that Darwin was certainly aware of and responsive to German thinking, his real roots lay in his own country. I argue that the real influences on him were the industrialists of his day and their supporters. The wealth that supported Darwin and his wife, his first cousin, was founded on the use of machines and the socio-economics (such as that of Adam Smith) that enabled such machines to be used to the full, to fill the coffers of their inventors and owners. The machine-like view of the world, reinforced by his mother's and wife's Unitarian (and hence deistic) connections, was one that coloured all of Charles Darwin's thinking about organisms and their origins. See Richards (2004) and Ruse (2004).

In fact, things did not happen this way at all. With the help of concordances, printed and computerized, I have surveyed all of Darwin's major and several not-so-major works. He simply does not speak of natural selection as a mechanism. He does not use the language of the 'nature is a machine' general metaphor at all. This does not occur in the *Notebooks*, in the earlier essays (the *Sketch* and the *Essay*), in the *Origin of species* (early or late editions), the *Descent of man*, or the *Expression of the emotions*. He does not do so in the *Variation under domestication*, a significant omission because, in his initial discussion in this work of the topic of selection, Darwin is at a point where he might naturally have done so. He is defending the use of the metaphor of natural selection, and he admits that his language is all rather anthropomorphic, inasmuch as it implies that the force of evolution is a power or an intelligent being. But, Darwin does not say that he is using selection as a mechanism or as something akin to a machine. He says simply: 'I mean by nature only the aggregate action and product of many natural laws,—and by laws only the ascertained sequence of events' (Darwin, 1868, Vol. 1, p. 6).

Given how much Darwin wrote, the many editions of the books, the papers, the thousands of letters that are only now being published, it would be a foolhardy person who claimed that Darwin never referred to selection (or any rival cause) as a mechanism, but one can say that this was absolutely not the typical language that he used about his theory in the prime creative years. Moreover, and this is what is striking, Darwin's failure to speak of selection as a mechanism did not stem from his unwillingness to speak of mechanisms. From the beginning, from before he was an evolutionist, he was prepared openly to use the metaphor of mechanism in the specific sense, of mechanism as a contrivance. At times, his use is unselfconscious. At times, particularly when selection is on the table, his use is deliberate. Either way, he outdid Boyle. Thus in the *Voyage of the Beagle*, in a non-evolutionary context, we have:

> When we were at Bahia, an elater or beetle (Pyrophorus luminosus, Illig.) seemed the most common luminous insect. The light in this case was also rendered more brilliant by irritation. I amused myself one day by observing the springing powers of this insect, which have not, as it appears to me, been properly described . . . The elater, when placed on its back and preparing to spring, moved its head and thorax backwards, so that the pectoral spine was drawn out, and rested on the edge of its sheath. The same backward movement being continued, the spine, by the full action of the muscles, was bent like a spring; and the insect at this moment rested on the extremity of its head and wing-cases. The effort being suddenly relaxed, the head and thorax flew up, and in consequence, the base of the wing-cases struck the supporting surface with such force, that the insect by the reaction was jerked upwards to the height of one or two inches. The projecting points of the thorax, and the sheath of the spine, served to steady the whole body during the spring. In the descriptions which I have read, sufficient stress does not appear to have been laid on the elasticity of the spine: so sudden a spring could not be the result of simple muscular contraction, without the aid of some *mechanical* contrivance. (Darwin, 1845, p. 30;

> here, and in subsequent quotations, I have italicized the language of machine or mechanism)

Likewise in the *Barnacle* books:

> Alcippe, according to Mr. Hancock, attacks only dead shells of the Fusus and Buccinum, and always on their inner sides, especially on the columella. The excavations, in the specimen which I examined, were so numerous as almost to touch, and sometimes to run into each other, the included animal being thus rendered distorted. The orifices are directed with respect to the shell indifferently upwards or downwards. From the shape and size of the cavity corresponding to that of the included animal, there can be no doubt, as stated by Mr. Hancock, that Alcippe forms its own cavity. That the action is *mechanical* I think may safely be inferred from the whole outer membrane being studded with minute, star-headed points of hard chitine, which rise from halo-like little discs of thickened membrane, which latter are well adapted to allow the underlying adherent muscular layer to act on the points, and thus on the surrounding shell. (Darwin, 1854a, pp. 549–550)

Notice that, as with Boyle, it is in the final cause (a term Darwin often uses) context, the adaptation context, that Darwin uses the language of mechanism. (Mechanism in the specific sense, that is Definition **1** in the dictionary.) Since natural selection is intended to explain adaptation, we expect to find that it is in such contexts that Darwin will really use the metaphor—and he does. In the third edition of the *Origin* (1861), for instance, he sets up the problem in this language.

> It may be doubted whether sudden and considerable deviations of structure such as we occasionally see in our domestic productions, more especially with plants, are ever permanently propagated in a state of nature. Almost every part of every organic being is so beautifully related to its complex conditions of life that it seems as improbable that any part should have been suddenly produced perfect, as that a complex *machine* should have been invented by man in a perfect state. (Darwin, 1959, p. 121)

And in the little book on orchids—the most important of all of Darwin's writings for showing how he thinks that selection will actually work—he constantly uses the machine metaphor to make his point.

> When I first examined these flowers I was much perplexed: trying in the same way as I should have done with a true Orchis; I slightly pushed the protuberant rostellum downwards, and it was very easily ruptured; some of the viscid matter was withdrawn, but the pollinia remained in their cells. Reflecting on the structure of the flower, it occurred to me that an insect in entering to suck the nectar, from depressing the distal portion of the labellum, would not touch the rostellum; but that, when within the flower, from the springing up of the distal half of the labellum, it would be almost compelled to back out parallel to the stigma by the higher part of the flower. I then brushed the rostellum lightly upwards and backwards with the end of a feather and other such

> objects; and it was pretty to see how easily the membranous cap of the rostellum came off, and how well, from its great elasticity, it fitted the object, whatever its shape might be, and how firmly it clung to it from the viscidity of its under surface. Together with the cap large masses of pollen, adhering by the threads, were necessarily withdrawn.
>
> Nevertheless the pollen-masses were not nearly so cleanly removed as those which had been naturally removed by insects. I tried dozens of flowers, always with the same imperfect results. It then occurred to me that an insect in backing out of the flower would naturally push with some part of its body against the blunt and projecting upper end of the anther which overhangs the stigmatic surface. Accordingly I so held the brush that, whilst brushing upwards against the rostellum, I pushed against the blunt solid end of the anther (see Sect. C); this at once eased the pollinia, and they were withdrawn in an entire state. At last I understood the *mechanism* of the flower. (Darwin, 1862, pp. 99–100)

And again:

> Still more interesting is this genus in its *mechanism* for fertilisation. We see a flower patiently waiting with its antennæ stretched forth in a well-adapted position, ready to give notice whenever an insect puts its head into the cavity of the labellum. The female Monachanthus, not having pollinia to eject, is destitute of antennæ. In the male and hermaphrodite forms, namely Catasetum tridentatum and Myanthus, the pollinia lie doubled up, like a spring, ready to be instantaneously shot forth when the antennæ are touched; the disc end is always projected foremost, and is coated with viscid matter which quickly sets hard and firmly affixes the hinged pedicel to the insect's body. The insect flies from flower to flower, till at last it visits a female or hermaphrodite plant: it then inserts one of the masses of pollen into the stigmatic cavity. When the insect flies away the elastic caudicle, made weak enough to yield to the viscidity of the stigmatic surface, breaks, and leaves behind the pollen-mass; then the pollen-tubes slowly protrude, penetrate the stigmatic canal, and the act of fertilisation is completed. Who would have been bold enough to have surmised that the propagation of a species should have depended on so complex, so apparently artificial, and yet so admirable an arrangement? (Ibid., pp. 247–248)

What is fascinating is that Darwin uses the metaphor to explain aspects of nature that are machine-like in distinctive or peculiar ways. In particular, he makes the point that nature has to make do with what it has rather than with what it would like to have. Hence, often, contrivances come out as though they were designed by (what the English would recognize as coming from) Heath Robinson or (what the Americans would recognize as coming from) Rube Goldberg.

> Although an organ may not have been originally formed for some special purpose, if it now serves for this end we are justified in saying that it is specially contrived for it. On the same principle, if a man were to make a *machine* for some special purpose, but were to use old wheels, springs, and pulleys, only slightly altered, the whole *machine*, with all its parts, might be said to be

> specially contrived for that purpose. Thus throughout nature almost every part of each living being has probably served, in a slightly modified condition, for diverse purposes, and has acted in the living *machinery* of many ancient and distinct specific forms. (Ibid., p. 348)

4. Nature as machine and nature as contrivance

Contrary to expectation, Darwin does not use the general metaphor—natural selection as a mechanism—but he does use the specific metaphor—organic parts as mechanisms. How are we to understand this? Although it is interesting, I do not want to read too much into the failure to use the mechanism language for natural selection. We know that Darwin was highly sensitive to the philosophies of science of his day, and generally those that he read were not into the language of mechanism for the world taken as a whole (Ruse, 1975). In particular, people such as John F. W. Herschel and William Whewell (to take the two who had the greatest influence on Darwin) were practising and sincere Christians, thinking that force was a reflection of God's will. Although they were certainly in the Boyle tradition of thinking of nature as a systematic network of law-governed events, they were not in the business of flaunting their naturalism or mechanistic approach to nature. They would use machine metaphor language when talking about issues in physics. Herschel, for instance, talks of the 'division of fluids, in mechanical language, into compressible and incompressible' (Herschel, 1830, p. 225). But at a more general level, they talk of laws and causes (particularly *verae causae*, the best kinds of causes). Whewell particularly, arguing explicitly that organisms come through non-natural forces, could never have used 'mechanism' generically for causes or processes, if this was to encompass organic origins. Indeed, believing that each area of science has its own fundamental principles ('Ideas'), he was not about to allow full mechanical language and understanding for chemistry: 'in attempting to advance a theory of Causes in chemistry, our task is by no means to invent laws of *mechanical* force, and collections of forces, by which the effects may be produced. We know beforehand that no such attempt can succeed' (Whewell, 1840, Vol. 2, p. 264; his italics).[2]

There is no question that Darwin went further than his teachers and mentors—further than anyone—in regarding nature as a machine. The metaphor was there, even if not the language. This was what Darwin was about. Not just chemistry, but biology also. To his friends Charles Lyell and Asa Gray, who were wriggling to find some kind of special forces for organisms—special forces that would guide evolution, and take the sting out of the lawlike nature of history—Darwin was blunt

[2] It has been pointed out to me by a referee that, by the eighteenth century, mechanism in the general sense of being subject to unbroken law was linked to materialism. The chemist Joseph Priestley referred to 'mechanism' as 'the undoubted consequence of materialism' (Priestley, 1782, Vol. 1, p. 5; cited in the *Oxford English dictionary* under 'Mechanism, *n.* I. 4'). There would have been no way in which Herschel and Whewell could have endorsed this philosophy. Nor, for all that he was making a radical break with the past, would we have expected to see such language in the writings of their disciple Charles Darwin.

to the point of rudeness (Ruse, 1979). There was to be no compromise here. It is law all the way down. Even chance is taken merely as a mark of ignorance rather than something ontologically or epistemologically significant. And as Darwin's own religious beliefs moved from the theistic Christianity of his youth, to a kind of deism (held when he became an evolutionist and right through the writing of the *Origin*), and on to agnosticism in his old age, I suspect he would have been happy to think of the metaphor as increasingly moribund and finally dead. The world is like a machine—definition **2** in the dictionary—but it isn't really one. Leave it at that.

More interesting is Darwin's use of the other sense of the metaphor—definition **1**—the specific one that sees organic parts as machine-like, as mechanisms. This was language that he found in the writings of his mentors. Paley's *Natural theology* was the biggest influence of all on Darwin in this respect, and opening randomly one finds: 'Movable joints, I think, compose the curiosity of bones; but their union, even where no motion is intended or wanted, carries marks of mechanism and of mechanical wisdom' (Paley, 1819, [1802], p. 86). Darwin takes this kind of language and thinking on board, fully. Of course, he transforms it with his explanation of natural selection, and this leads to new insights, for instance about the ramshackle nature of so many adaptations, doing with what they have rather than what they would like to have. But the very last thing Darwin wants to do is drop or belittle the metaphor (Ruse, 2003). Seeing nature's parts as machines, as mechanisms, as contrivances, is absolutely crucial for Darwin. Like a vampire before a virgin, the metaphor takes on new life. It is the key, heuristic tool for the student of natural selection. One has the force. Now, how is one to apply it? Think of organisms and their parts as if they were machines, and puzzle out the solution. This is what Darwin does in his study of orchids and this is what he invites his readers to do. (Today, this is known revealingly as 'reverse engineering'.)

So, reverting again to the philosophical world, what would I want to conclude here? To make a full case for the thesis that the theory of evolution through natural selection is objectively true, one would need to run through the theory showing how it manifests epistemic excellence—that it is predictive, consistent, coherent and so forth. Although I have tackled this issue elsewhere, here the claim will have to be taken on trust (see Ruse 1982, 1999, 2006, forthcoming) What can be said here is that the epistemic success of the general 'nature is a machine' metaphor—leading to definition **2**—and its increasing divorce from the notion of an actual creator, underlines the truth of the thesis. Inasmuch as Darwin's theory participates in this metaphor, and it does, it is on the track towards objectivity. In fact, I would say that the success of evolution and natural selection as instruments of science (with respect to epistemic virtues such as unification and predictive fertility) is a major reason why it is proper to conclude that science is really about something and not just a construction. (It is worth noting that Darwin himself was sensitive to the need for epistemic excellence and went out of his way to argue that his theory lived up to the demands. For example: 'The present action of natural selection may seem more or less probable; but I believe in the truth of the theory, because it collects under one point of view, and gives a rational explanation of, many apparently independent classes of facts' (Darwin, 1868, Vol. 1, pp. 13–14).)

At the same time, the ongoing importance of the metaphor of the machine in understanding contrivance, adaptation, suggests that the claim that science is purely objective—'knowledge without a knower', in Popper's (1972) felicitous phrase—is too strong a thesis. Live metaphors, rooted in culture, structure and inform our experience and are not about to vanish. In the case of Darwin's theory of evolution through natural selection, the vision of organic parts—bits of the orchid or of the barnacle—as machine-like, as mechanisms (definition **1**), is absolutely vital to an understanding of how these bits or systems work. The very questions posed—how does fertilization in the orchid take place—are framed in terms of the metaphor of organic parts as machine parts. Why even ask about the bits and pieces unless you are trying to tie them together in a mechanical fashion? You see bits of metal on the ground but unless you are thinking of them as parts of a watch or whatever, they make no sense at all. Likewise with the plants.

But notice that machines, particularly complex machines, are part of human culture—'Lucy' (*Australopithecus afarensis*) did not have them. Even if *A. afarensis* had been able to think conceptually (and Lucy surely could at some level), she could never even have asked Darwin's questions, let alone solved them. She did not live in a world of telescopes and watches and automobiles and computers. She could of course have asked questions about differential reproduction, and noted that some barnacles or orchids seem to survive and reproduce and others do not, but she could not have asked why the successful succeed and the unsuccessful fail. So she could have had an evolutionary theory, but by our standards it would have been impoverished. To get Darwin's theory, to get something so triumphant as objective science, you need the metaphors, and this brings in the subjective side of culture.

5. Evolution after Darwin

But that was back then. What about now? Darwin was a pioneer. Perhaps, in the hundred and fifty years since the *Origin*, things have changed. Perhaps one side of the machine metaphor (the general side) was already back then on its way to its grave, and the other side (the specific side) would follow in the years subsequent? Actually, however—and here I will move very quickly—this seems not to be the case. Things are still much as Darwin left them. It was not long before people did actually start to use the language of mechanism about natural selection and other putative causes. This was part and parcel of the move to secularize science completely, and to use it as a tool of social reform and more. By 1873, for instance, Thomas Henry Huxley—who as the archetypical agnostic wanted nothing to do with God or with ideas of the world as His creation—was reducing everything to the blind workings of law, leading in a deterministic fashion to their inevitable ends: 'the whole world, living and not living, is the result of the mutual interaction, according to definite laws, of the forces possessed by the molecules of which the primitive nebulosity of the universe was composed'. What we cannot now say is that the end to which all of this leads has any purpose. The universe works like a clock, but we have no right to say that the purpose is telling time any more than that the purpose is

senseless ticking. In this world, the forces that control all of this—including all of this in the world of organisms—are mechanisms. 'And there seems to be no reply to this inquiry, any more than to the further, not irrational, question, why trouble oneself about matters which are out of reach, when the working of the *mechanism* itself, which is of infinite practical importance, affords scope for all our energies?' (Huxley, 1873, pp. 272–274). So it went. (It is for this reason that if someone discovered that Darwin in the 1870s referred to natural selection as a mechanism, I would take it as confirmation rather than refutation of what I have written above. By the 1870s, he was an agnostic, like—and under the influence of—Huxley, and if Darwin adopted the language of mechanism for causes, this would be part and parcel of the same general picture.)

As is well known, natural selection never gained much favour in Darwin's own lifetime. Although around the beginning of the twentieth century there was a group, the biometricians, who became selection enthusiasts, natural selection really had to wait until the 1930s before it started to take off as the generally acknowledged, central, causal force behind evolutionary change. By then, people—including religious people—referred unselfconsciously to selection and other putative causes as mechanisms.[3] Theodosius Dobzhansky, in his *Genetics and the origin of species*, tells his reader that '*mechanisms* that counter-act the mutation pressure are known to exist. Selection is one of them . . . ' (Dobzhansky, 1937, pp. 37–38). And again: 'In its essence, the theory of natural selection is primarily an attempt to give an account of the probable *mechanism* of the origin of the adaptations of the organisms to their environment, and only secondarily an attempt to explain evolution at large' (ibid.,

[3] I do not know who actually first called natural selection a 'mechanism'. I would not be surprised to find that it was an American, although expectedly (given that he was an evangelical Presbyterian) Asa Gray never uses this term of selection in his collected essays *Darwiniana*. (As expectedly, he constantly likens contrivance to machine-like processes.) In 1897, in *The survival of the unlike*, Liberty Hyde Bailey refers to natural selection as a hypothesis about the 'controlling process or factor in evolution' (Bailey, 1897, p. 57), although he does use the language of machinery to talk about heredity (ibid., p. 64). However, in his survey of evolutionary theories of 1907, *Darwinism today*, Vernon L. Kellogg tells us that he is after the 'factors and mechanism of organic evolution' (Kellogg, 1907, p. iii), and at the end of the book concludes that 'Darwinism as the all-sufficient and even most important causo-mechanical factor in species-forming and hence as the sufficient explanation of descent, is discredited and cast down' (ibid., p. 374). A quick search of the online works of the pragmatists C. S. Peirce and William James (including *Pragmatism* and the *Varieties of religious experience*) does not suggest that the philosophers would have been key influences on the biologists. I find that the English at this time do not generally use the term 'mechanism' to refer to selection. Certainly (covering myself against an atypical occurrence) one can say that the general trend is not to use the term in this sense. This is true of the Darwinian book, *The colours of animals*, by the Oxford biologist E. B. Poulton (1890). Checking a little book written in 1912, *The evolution of living organisms*, that (to the best of my knowledge) first synthesizes selection and Mendelian genetics in a full fashion, I find that the author (the English anatomist E. S. Goodrich) refers to Mendelism as a 'mechanism', but calls selection a 'factor' or 'process'. Perhaps as people became more and more comfortable in seeing Darwinian selection and Mendelian genetics as complements, they decided that sauce for the Mendelian goose should also be sauce for the Darwinian gander. But even R. A. Fisher in his *The genetical theory of natural selection* of 1930 and J. B. S. Haldane in his *The causes of evolution* (1932) do not come right out with the language.

p. 150). (I suspect that this reading of the *Origin* would be news to its author.) More negatively from Sewall Wright, who was such an influence on Dobzhansky: 'That evolution involves nonadaptive differentiation to a large extent at the subspecies and even the species level is indicated by the kinds of differences by which such groups are actually distinguished by systematists'. Apparently only when you start to get up to the subfamily or family level do you start to get adaptive difference. 'The principal evolutionary *mechanism* in the origin of species must thus be an essentially nonadaptive one' (Wright, 1986 [1932], pp. 168–169). More positively, over in England, we find Julian Huxley defending selection against various kinds of saltationism (evolution by macromutations) and pointing out that the 'difference lies in the intermediary steps: in the one case the effect of use or function is supposed to be direct, in the other indirect, *via* the sifting *mechanism* of selection' (Huxley, 1942, p. 39).

Finally, jumping to the present, let us turn to the first page of today's standard text on evolution: *Evolutionary analysis* by Scott Freeman and Jon C. Herron.

> Where did Earth's organisms come from? Why are there so many different kinds? How did they come to be so apparently well-designed to live where they live and do what they do? These are the fundamental questions of evolutionary biology. The answers are found in both the pattern and the *mechanism* of evolution. The pattern of evolution is descent with modification from common ancestors. The principle *mechanism* that drives this change is natural selection. (Freeman & Herron, 2004, p. 1)

What about the more restricted use of mechanism as contrivance? Again, we can find that evolutionists in the Darwinian mode have used the metaphor right up to the present. Indeed, one of today's most influential thinkers, George Williams, has been explicit on this point.

> Whenever I believe that an effect is produced as the function of an adaptation perfected by natural selection to serve that function, I will use terms appropriate to human artifice and conscious design. The designation of something as the means or *mechanism* for a certain goal or function or purpose will imply that the *machinery* involved was fashioned by selection for the goal attributed to it. When I do not believe that such a relationship exists I will avoid such terms and use words appropriate to fortuitous relationships such as cause and effect. (Williams, 1966, p. 9)

In this mode, when it comes to actual studies, the language of mechanism is used for adaptations. For instance, following standard Darwinian theory, David Reznick argues that fish that are heavily predated as adults will mature quickly, so that their reproduction can occur before they are killed and eaten. This is an adaptation to a specific situation. Fish that are eaten with less discrimination, and especially fish that are eaten young, will have no such selective pressure driving them this way. With great skill and subtlety Reznick was able to show that precisely these results hold for various little fish to be found in rivers in islands on the island of Trinidad. Comparing two specific locations (high-predation patches were called generically 'Chrenicichla' localities, and low-predation patches were called 'Rivulus' localities),

Reznick employed what is called the 'mark-recapture' technique, where one simply catches all of the fish (in his case, guppies) in a particular location, marks them in some definite way so that they will not be confused with others, and then one releases them back. Later one catches them all again—at least one catches again all of those remaining—and thus one can do comparative checks on the rates of predation. One can actually see if indeed the prey is being eaten by the predators (Reznick et al., 1996).

> If the differences in predation caused differences in guppy mortality rates, then the recapture probabilities of guppies from Crenicichla localities should be lower. If the Crenicichla prey selectively on adults, then the difference in mortality should be more dramatic for the adult age classes. We did, indeed, find that the overall probability of recapture was substantially and significantly lower in Crenicichla localities, implying higher mortality rates. (Reznick & Travis, 1996, p. 269).

As Reznick somewhat triumphantly concludes: 'Such a result reveals a potential *mechanism* of life history evolution and thus goes a step farther in arguing that the differences in guppy life histories among Crenicichla and Rivulus localities represent an adaptation to predator induced mortality' (ibid.).

I appreciate that not every evolutionist today is an ardent Darwinian, and those who are not are probably going to downplay the significance of selection and adaptation, and hence the importance of the 'contrivance as mechanism' metaphor. My point is that those evolutionists who are Darwinians—and by far the biggest number of professional evolutionists do fall into this camp—follow Darwin himself. They accept and use the 'contrivance as mechanism' metaphor, thinking it indispensable to their studies. Without it, they lose one of their most powerful heuristic tools.

6. Conclusion

My conclusion follows quickly and simply. Metaphor generally is important in science. The machine metaphor specifically has played a very important role in science—it is at the base of much of the epistemic triumph of science. Its more general reading—the world as a machine—is endorsed and accepted fully by the Darwinian evolutionist, although (as for other scientists) in important respects this is now a dead metaphor. The more specific reading—the parts of organisms are to be seen as mechanisms functioning for some end, created by and aiding natural selection—is absolutely crucial to modern evolutionary biology. This sense of the metaphor thrives mightily. It is an essential component of the predictive fertility of Darwinian evolutionary theory, and neither the past nor the present gives one reason to think that it will be eliminated. Thus, to repeat what I said at the end of the discussion of Charles Darwin's own work, the general reading of nature as a machine—nature as a lawbound system of events—lies beneath the justifiable claims of science to yield objective knowledge. This holds true of Darwin's own theory of evolution

through natural selection, even more today than it did in his day. The specific reading of nature as a machine—organisms as composed of contrivances, as made of machine-like mechanisms—likewise thrives in today's (neo-Darwinian) evolutionary biology. In fact, indirectly it contributes to the epistemic excellence of the science. However, today no less than yesterday, the metaphor is one drawn from culture, and is not a necessary component of human thought or even of evolutionary thinking—although an evolutionary theory without the specific metaphor would be much impoverished. In this regard, because today's evolutionists do use the metaphor, neo-Darwinian science continues to have its subjective side. Given the success of the science, it would seem silly if the philosopher—in the name of some kind of epistemic purity—were to object to the way that things are. In the real world, science—the best science—reflects the human beings who create it.

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