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Why did the stegosaurus have plates, or is biology second-rate because it thinks in terms of ends?

¿Por qué el estegosaurio tiene placas, o es la biología una ciencia de segunda clase porque piensa en términos de fines?

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Abstract

There is something distinctively different about explanation in the biological sciences, as opposed to explanation in the physical sciences. In the former one has functional arguments, arguments making reference to what Aristotle called "final causes." As in: "The function of the plates on the back of the Stegosaurus was to keep the body at a constant temperature." Since the Scientific Revolution, such explanations have been forbidden in the physical sciences. Does this then mean that biology is second rate, as is suggested by many including Immanuel Kant? It is argued that the Darwinian mechanism of natural selection explains why there is need of functional explanation in biology and that once this point is grasped, there is no reason to judge biology second rate.

Keywords: Stegosaurus, final cause, adaptation, Charles Darwin, natural selection.

Resumen

Hay algo distintivamente diferente en la explicación propia de las ciencias biológicas, en tanto opuesta a la explicación en las ciencias físicas. En las primeras tenemos argumentos funcionales, argumentos que hacen referencia a lo que Aristóteles llamó "causas finales"; por ejemplo, "La función de las placas de la parte posterior del estegosaurio era mantener el cuerpo a una temperatura constante". Desde la Revolución Científica, explicaciones de este tipo han sido prohibidas en la física. ¿Significa esto que la biología es de segunda clase, como sugieren algunos, entre ellos Immanuel Kant? Se defenderá en este artículo

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que el mecanismo darwiniano de selección natural explica por qué hay necesidad de una explicación funcional en biología y, que una vez que se comprende este punto, no hay razón para juzgar a la biología como ciencia de segunda clase.

Palabras clave: Estegosaurio, causa final, adaptación, Charles Darwin, selección natural.

> Stegosaurus plates have been viewed as "armor" or as anatomical structures that enhanced species-specific agonistic and sexual displays. Whatever the merits of these suggestions, the plate morphology and experimental and computational evidence assembled and discussed below suggest an important thermoregulatory function. We hope to demonstrate that their arrangement, size, shape, and probable vascularity ensured their value as convective heat loss fins, not unlike those currently used to enhance forced convective heat transfer in compact engineering devices. (Farlow, Thompson, and Rosner 1976, 1123)

1. Function talk and its discontents

This is an opening paragraph of a ground-breaking article on the plates that run along the back of the dinosaur, Stegosaurus, a herbivorous, Jurassic (about 150 mya) dinosaur (Figure 1). They long puzzled paleontologists as to the reason why they were there, why they had the shape they had, and why they were spaced in the way that they are. As you can see, several suggestions had been made, none entirely satisfactory. Perhaps they are armor for use when the animal is fighting or being attacked? The trouble is that the bone structure suggests that they would snap off almost immediately. Perhaps they are used for attracting mates? But then why do both males and females have them? Perhaps they are easy recognition appendages? Now comes the suggestion that they are for heat regulation. Dinosaurs are reptiles, meaning that they are cold-blooded, they don't (unlike mammals and birds) have internal heat regulators. So they rely on external factors for heat control, and the fins are perfect for cooling the brutes down in the heat of the day. Instead of having to hide in the shade, they can go about their everyday business, thanks to their cooling blades. (This would have been important for the Stegosaurus. It was a herbivore, with a five ton body, so, like sheep and cows and other herbivores today, would have needed to spend a great deal of time foraging for the low-grade fuel on which it existed. Sleeping the day away under a bush was not an option. That is for carnivores, who need only few intakes of their high-grade fuel. Think how much time dogs spend sleeping.)

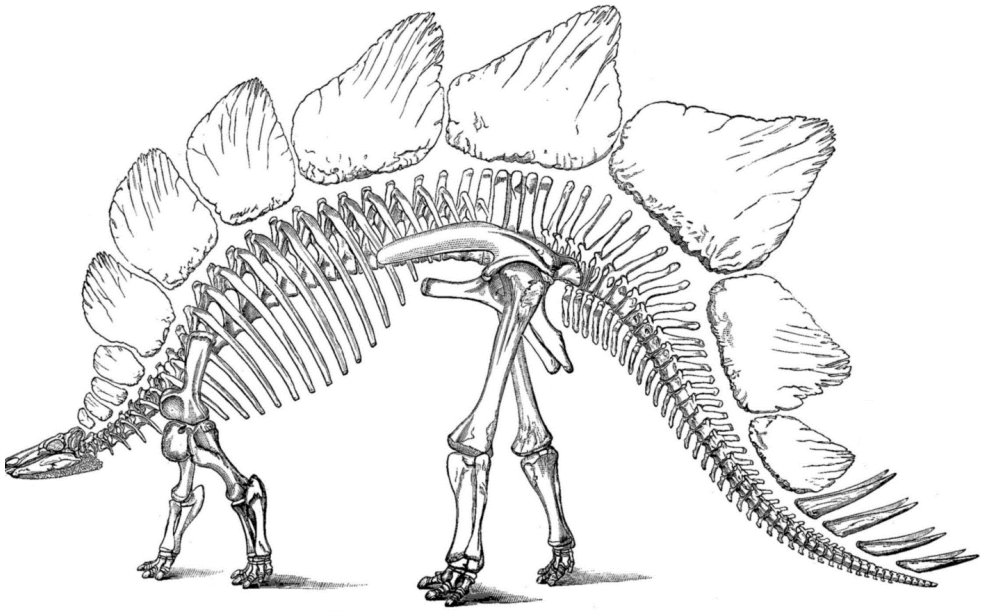

Figure 1.

Note some interesting features about this explanation. The authors use the word "function." They ask about the function of the plates. The authors use the word "value," in trying to determine why the beasts have the plates. The authors use an analogy, drawing attention to the similarity between the Stegosaurus plates and those found in "compact engineering devices." In these respects, the explanation differs from the kind of explanation one finds in the physico-chemical sciences. No one is going to ask about the function of the moon. You might reply humorously that it is to light the way home for drunken philosophers, but although apparently in the eighteenth century it was so used by members of the Lunar Society (a monthly meeting of a group of British businessmen and inventors), that is not an explanation from physics. The moon does its thing according to unbroken law. It doesn't have any function. Things in the physico-chemical sciences don't have values. Those are for human things, and as Karl Popper (1972) reminded us, "science is knowledge without a knower." Human interests and desires don't come into it. I might regret global warming, but all that science can do is tell us if it is happening and how fast. Finally, it is certainly the case that you can get analogies in physics and chemistry. Trying to show how it is that gravity keeps the spinning moon from flying off into space, John F. W. Herschel (1830) drew the analogy of a stone tied to a piece of string, that is then made to go whizzing in circles around your finger. He tells us that we feel a tug from the stone trying to fly off, that we prevent by pulling on the string. Our pulling is the same as gravity. Gravity prevents the moon from leaving. Notice, however, that the stone on the string going around the finger has no point to it. It is not designed for

anything. It has no end. This is the difference with compact engineering devices. They do have an end, a purpose, a function – cooling things down in a hydroelectric generating towers, for instance.

One final point. The language and the way of thinking of these authors is not one-off or a moment's aberration or laziness or whatever. Thinking in terms of function is central to the argument. I quote the conclusion of a follow-up article.

> If we now compare the various hypotheses put forward to account for the function of Stegosaurus plates, our histological data suggest the following: First, the classic reconstruction of the plates in a subvertical position is substantiated beyond any reasonable doubt. Second, it is highly unlikely that the plates could change their orientation from a recumbent to an erect one or vice versa through contraction of epaxial musculature. Third, the plates could not function as a plating or armor in the usual sense. Fourth, the display function of the plates, either for in transpecific or interspecific interactions, remains a distinct possibility which is not, moreover, mutually exclusive with other possible functions. Whatever their possible primary adaptive significance, the plates did enhance or otherwise modify the dinosaur's apparent size and shape. Fifth, the physiological function of the plates as parts of a thermoregulatory system seems a plausible interpretation. We believe that a thermo regulatory interpretation of plate function remains, with some modifications (emphasizing the role of the skin and perhaps minimizing the role of the bony plate itself in the heat exchange device), the most robust hypothesis presently available, as it better accounts for anatomical, histological, and paleoecological data than any competing functional hypothesis. (de Buffrénil, Farlow, and Ricqulès 1986, 473)

These articles appeared in top-level journals – first the weekly *Science, the* major, weekly, scientific publication, and then *Paleobiology*, the definitive home for paleontological articles with a biological interest. You don't get more professionally respectable than this. These are the kinds of homes you virtually put in neon signs on your cv when you are hoping for tenure or promotion.

So here is my question. Function-talk is what philosophers call "teleological" talk (Ruse 2017). In historical terms, it is what Aristotle would have called "final cause" talk, as opposed to the normal kind, physico-chemical-acceptable, "efficient" cause talk. What does this mean and why would it be worrisome? The answer is this. Causes produce effects. Let's suppose we have a Heinrich Himmler sort of case, where I have been captured by the Allies and, in order to escape trial and execution, I commit suicide. I swallow prussic acid and moments later I drop dead. Analyze this. Cause: I swallow the prussic acid. Effect: I drop dead. When we use efficient-cause thinking, the cause always precedes or is simultaneous with the effect. Swallow the acid. Five minutes later, heart stops beating. When you talk about the effect, you know the cause occurred or is occurring. However, with final-cause talk – function talk – you are referring to the future. I swallowed the acid in order to kill myself. The cause of what is going on is in the future. Cause: I want to die (future). Effect: I swallow the acid (past or present).

Now, here's the rub. With efficient causes, if you have the effect – dropping dead – you know the cause occurred – swallowing acid. With final cause, if you have the effect – swallowing acid – the cause might or might not occur. You hope for and explain in terms of an end, and then the end never comes. Someone might immediately inject you with an antidote and your heart never misses a beat. That means you might be explaining things in terms of the non-existent! The problem of the "missing goal object." I swallowed the acid to drop dead, but I didn't drop dead, so how can swallowing the acid be explained in terms of dropping dead? Likewise with the Stegosaurus plates. The Stegosaurus grew plates to be nice and cool on sunny days. Unfortunately, just as baby Stego was about to set out on life, a nasty carnivore came along and spoilt everything. Plates for cooling. No cooling. How then can the plates be for cooling?

In the human case, we have an obvious and pretty good answer. It's the thought that counts! What motivated my acid-swallowing was not the actual dropping dead but my thought that, if I drink the acid, I will drop dead. The thought is an efficient cause which has already occurred when I drop dead. The thought is unchanged whether or not I drop dead. I still thought I would drop dead by swallowing the acid. Unfortunately you cannot play that sort of trick in the non-human world. The Stegosaurus plates didn't have the thought of cooling down their owner, whether or not it did do any cooling. No thoughts. No way out of the dilemma. What's the conclusion? That biologists are simple, sloppy folk, who anthropomorphize their subject matter no less that a shaman among the savages who thinks that trees have life and feelings and carry on conversations when no one is around in the forest. No wonder that biology is a second-rate science.

Such at least was the opinion of the great German philosopher Immanuel Kant. You want to make the life sciences equal to the physical sciences? Faint hope! "We can boldly say that it would be absurd for humans even to make such an attempt or to hope that there may yet arise a Newton who could make comprehensible even the generation of a blade of grass according to natural laws that no intention has ordered; rather, we must absolutely deny this insight to human beings" (Kant 1790, 271). Can we help biology at this point? I believe we can. I am an evolutionist and I believe that the answer to today's problems and questions are almost always to be found in the past. Let us therefore then follow my intuition.

2. The legacy of Greece

If we go back to the Ancient Greeks, the main foundation for Western thought, there were those who simply dismissed the whole question as bogus. Ends are irrelevant, because everything happens by chance. What eventually happens has no relevance to what has gone before. The atomists, Leucippus and his student Democritus, argued that all of reality is particles buzzing around in space. Sometimes they cohere and work, but not

for any good reason. They stick together just because they do. The Roman poet Lucretius, several centuries later, following another atomist Epicurus, a follower of Democritus, gave the fullest exposition.

> At that time the earth tried to create many monsters
> with weird appearance and anatomy—
> androgynous, of neither one sex nor the other but
> somewhere in between; some footless, or handless;
> many even without mouths, or without eyes and blind;
> some with their limbs stuck together all along their body,
> and thus disabled from doing harm or obtaining anything
> they needed.
> These and other monsters the earth created.
> But to no avail, since nature prohibited their development.
> They were unable to reach the goal of their maturity,
> to find sustenance or to copulate.

Thus far, nothing works. It is just a mess, of no value whatsoever. But then, given infinite time, things joined up in functioning ways.

> First, the fierce and savage lion species
> has been protected by its courage, foxes by cunning, deer by
> speed of flight. But as for the light-sleeping
> minds of dogs, with their faithful heart,
> and every kind born of the seed of beasts of burden,
> and along with them the wool-bearing flocks and the horned tribes,
> they have all been entrusted to the care of the human race,
> (Lucretius 1969, 5.862-67)

All very well, but truly in the opinion of most sensible Greeks, completely implausible. Something like the plates on the back of the Stegosaurus just doesn't seem to be random particles sticking together. At least, such was the opinion of two of the greatest of the Greek philosophers, Plato and Aristotle, both of whom had things to say. Although, their different answers reflected the difficulties of getting to grips with the issue.

In the *Phaedo*, Plato recognized that there is more to understanding, especially about the organic world, that simple efficient-cause thinking. If I want to understand why my body builds, of course I am going to talk about food and the effect it has on body growth. But there is still the question of why we would want to grow – the question of why we would think it (and note here another of our flag words coming up) of value to grow. And here Plato extends what we have just being saying about human purpose or end thinking, to say that if not us then apparently some bigger, designing mind or Mind. "One day I heard someone reading, as he said, from a book of Anaxagoras, and saying that it is Mind

that directs and is the cause of everything. I was delighted with this cause and it seemed to me to be good, in a way, that Mind should be the cause of all. I thought that if this were so, the directing Mind would direct everything and arrange each thing in the way that was best" (Plato 1997, 97 c-d). So, now one has a guide to understanding and as a bonus a guide to discovery." Then if one wished to know the cause of each thing, why it comes to be or perishes or exists, one had to find what the best way was for it to be, or to be acted upon, or to act."

The function of the Stegosaurus plates is to cool the animal in the heat of the mid-day sun, and the reason for all of this is that an external Mind planned things that way. No problem with the missing goal object. If the Stegosaurus gets eaten before it can put its plates to use, it is still the case that the Mind did the planning. The Mind had the end in view before it started to make the plates. For Plato, as is well known, this Mind was not the Christian God – he was four centuries before Jesus, and he was not a Jew (so Yahweh was not on) – but rather the Form of the Good. In the *Timaeus* he identifies this with the Demiurge who is, not creator (everything is eternal), but Designer.

Plato is what is known as an *external* teleologist. His student Aristotle, who had been a practicing biologist, was an *internal* teleologist. Like Plato he thought that everything, organic and non-organic, can be given a final-cause explanation, but it was in the world of organisms where he thought this all-important. We need to know how things come about – efficient causes – but we need also to know the reasons why things come about – final causes.

> To say, then, that shape and colour *constitute* the animal is an inadequate statement, and is much the same as if a woodcarver were to insist that the hand he had cut out was really a hand. Yet the physiologists, when they give an account of the development and causes of the animal form, speak very much like such a craftsman. What, however, I would ask, are the forces by which the hand or the body was fashioned into its shape? The woodcarver will perhaps say, by the axe or the auger; the physiologist, by air and by earth. Of these two answers the artificer's is the better, but it is nevertheless insufficient. For it is not enough for him to say that by the stroke of his tool this part was formed into a concavity, that into a flat surface; but he must state the reasons why he struck his blow in such a way as to effect this, and what his final object was; namely, that the piece of wood should develop eventually into this or that shape. (Aristotle 1984)

Notice that, as always, value is the underlying theme. "In dealing with respiration we must show that it takes place for such or such a final object; and we must also show that this and that part of the process is necessitated by this and that other stage of it" (Barnes 1984, 642a32-34). The very essence of showing the final object of respiration is that of demonstrating that the process is of value to the organism that is respiring.

Where Aristotle differed crucially from Plato was in that he didn't want to appeal to an external designer, or Designer, but wanted it all to come from within, a kind of motive

or vital force. We should be careful however of thinking of this as a form of substance. In respects, it is more a principle of organization. Something demanding final-cause explanation is organized in a way that something not demanding such explanation is not. Aristotle had a supreme being, the Unmoved Mover. This is perfection and everything strives towards it, in the sense of trying to emulate it. It is no creator like the Christian God, nor is it a Designer like the Christian God or Plato's Demiurge. Indeed it does not even know of our existence for it does the only thing a perfect being can do, namely contemplate its own perfection!

The pattern was set now for nigh two thousand years. Both the external position of Plato and the internal position of Aristotle were Christianized, the former by Augustine and the latter by Aquinas. Because everyone now did believe in a good, creator-designer, the teleological aspect of the world, of organisms particularly, was taken as one of the definitive proofs of God's existence.

> We see that things which lack knowledge, such as natural bodies, act for an end, and this is evident from their acting always, or nearly always, in the same way, so as to obtain the best result. Hence it is plain that they achieve their end, not fortuitously, but designedly. Now whatever lacks knowledge cannot move knowledge and intelligence; as the arrow is directed by the archer. Therefore, some intelligent being exists by whom all natural things are directed to their end; and this being we call God. (Aquinas 1963, [1a. 75-83], 2, 3).

3. Kant's dilemma

It was the Scientific Revolution, from Copernicus at the beginning of the sixteenth century to Newton at the end of the seventeenth century, that spelt the end of this happy world picture. For the Greeks and their successors, the world was seen as a kind of super-organism – justified if only by its seasons. Spring's birth and growth, Summer's fullness of life, Autumn moving towards old age, and finally death with the return of Winter. Then the switch was made to the world as a machine, simply a contraption governed by unbreakable, eternal laws, endlessly going through the motions, with (unlike human-made machines) no ultimate purpose.

The physicist-philosopher Robert Boyle was good on this, arguing that the world 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, 12-13).

Yet Boyle had to admit that organisms still seemed to demand final-cause thinking. As he wrote in his "Disquisition about the Final Causes of Natural Things," happily taking the opportunity to make a philosophical point while putting the boot into the French: "For there are somethings 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 [followers of the French philosopher René Descartes], 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" (Boyle 1996, 5:397-98.). 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." Apart from anything else, not only does this take us from the chance to do science – 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" – it takes us away from the designing intelligence behind it.

Boyle was being forced into playing a double game here. His stance supposedly is not something threatening to the mechanical position. It complements it! How can this be so? Boyle is distinguishing between acknowledging the use of final causes qua science and the inference qua theology from final causes to a designing god. First: "the bodies of animals it is oftentimes allowable for a naturalist, from the manifest and apposite uses of the parts, to collect some of the particular ends, to which nature destinated them. And in some cases we may, from the known natures, as well as from the structure, of the parts, ground probable conjectures (both affirmative and negative) about the particular offices of the parts" (Boyle 1966, 5:424). Then, the science finished, one can switch to theology: "It is rational, from the manifest fitness of some things to cosmical or animal ends or uses, to infer, that they were framed or ordained in reference thereunto by an intelligent and designing agent." From a study in the realm of science, of what Boyle would call "contrivance," to an inference about design – or rather Design – in the realm of theology.

A solution, but not a happy one. It is true that the way is now opened for much good biological science, and one can justify it by saying one is doing God's work, but why should the organic world demand this dual approach when the inorganic world – surely as much the creation and design of the very same good God – does not? It is here, that a hundred years later at the end of the eighteenth-century, Immanuel Kant stepped in and gave his take on the problem. The world is not to be understood teleologically in any fundamental or ontological sense. However, because the future tends to be like the past, and because in the case of organisms we have an ongoing chain of causation, as a rule of thumb we can explain in terms of the expected future. Feature, consequence, leading again to feature, consequence, and so forth. Teeth, eating, leading to next generation with teeth, eating, leading to…. Although there is no guarantee that teeth will lead to eating

– like the baby Stego, a predator might spoil everything – so there can be no genuine scientific understanding, normally we expect teeth to lead to eating – they have in the past, so we expect them to do so in the future. It is a good bet. Hence, heuristically, we can rely on thinking – indeed, it proves invaluable – in the organic world.

> The concept of a thing as in itself a natural end is therefore not a constitutive concept of the understanding or of reason, but it can still be a regulative concept for the reflecting power of judgment, for guiding research into objects of this kind and thinking over their highest ground in accordance with a remote analogy with our own causality in accordance with ends; not, of course, for the sake of knowledge of nature or of its original ground, but rather for the sake of the very same practical faculty of reason in us in analogy with which we consider the cause of that purposiveness. (Kant 2000, 247)

This led to the harsh judgment that biology will never be as good as physics.

4. Charles Darwin and natural selection

Enter Darwin who was determined to be the Newton of biology. In his *Origin of Species*, published in 1859, he proposed his theory of evolution through natural selection. All organisms, living and dead, are or were part of the unifying tree of life. "As buds give rise by growth to fresh buds, and these, if vigorous, branch out and overtop on all sides many a feebler branch, so by generation I believe it has been with the great Tree of Life, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever branching and beautiful ramifications" (Darwin 1859, 130). The mechanism of change is natural selection. First Darwin argued to a struggle for existence.

> A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase. Every being, which during its natural lifetime produces several eggs or seeds, must suffer destruction during some period of its life, and during some season or occasional year, otherwise, on the principle of geometrical increase, its numbers would quickly become so inordinately great that no country could support the product. Hence, as more individuals are produced than can possibly survive, there must in every case be a struggle for existence, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life. (Darwin 1859, 63)

Then, from this, taking note that new variations seem always to arise in each generation of organisms, Darwin argued to natural selection.

> Let it be borne in mind how infinitely complex and close-fitting are the mutual relations of all organic beings to each other and to their physical conditions of life. Can it, then, be thought improbable, seeing that variations useful to man have undoubtedly occurred, that other variations useful in some way to each being in the great and complex battle of life, should sometimes occur in the course of thousands of generations? If such do occur, can

> we doubt (remembering that many more individuals are born than can possibly survive) that individuals having any advantage, however slight, over others, would have the best chance of surviving and of procreating their kind? On the other hand, we may feel sure that any variation in the least degree injurious would be rigidly destroyed. This preservation of favourable variations and the rejection of injurious variations, I call Natural Selection. (Darwin 1859, 80-81)

What is important here is that Darwin didn't think that natural selection merely leads to change, but rather change of a particular kind, namely that which is going to help its possessors. The eye is created as it is in order to see. The flower to attract pollinators. The fangs of the snake to kill. The instincts of the nest-building bird to promote and continue life:

> Under nature, the slightest difference of structure or constitution may well turn the nicely-balanced scale in the struggle for life, and so be preserved. How fleeting are the wishes and efforts of man! how short his time! and consequently how poor will his products be, compared with those accumulated by nature during whole geological periods. Can we wonder, then, that nature's productions should be far "truer" in character than man's productions; that they should be infinitely better adapted to the most complex conditions of life, and should plainly bear the stamp of far higher workmanship? (Darwin 1859, 83-84)

Note, Darwin is not denying the existence of God. Although later he became an agnostic, at this time he was a deist, thinking God works through unbroken law (Ruse 2015). However, like Boyle, Darwin felt that these sorts of thoughts belong to religion not to science. Science begins and ends with unbroken law. Where Darwin went beyond Boyle was in bringing organisms in from the cold. No longer must they be studied as part of theology or religion. They can now be studied as part of science. The Newton of the blade of grass, indeed!

5. Making sense of things

The story of course continues for another hundred and fifty years, down to the present. But the solution we accept today – the solution presupposed by our Stegosaurus investigators – is that of Darwin. Let us end our story by putting everything into historical context.

Darwin's theory of evolution through natural selection explains adaptation – the eye, the hand, the plates along the back of the Stegosaurus. Or, at least, let us say more accurately, Darwin's theory gives scientists the framework within which to explain adaptation (Ruse 2006). Darwin, as such, does not explain the hand or the eye or the plates. He gives investigators tools to tackle the problem. How is the feature under investigation going to help its possessor in the struggle to exist and to reproduce? Organisms with sight are better off than organisms without sight. (Always there are exceptions, in this case

cave-dwelling organisms that have no use for eyes and who would find them dangerous in the sense of being prone to infection and the like.) Organisms with hands are better off than organisms without hands. (Again exceptions. Whales have given up limbs, let alone hands, as have snakes.) Stegosauruses with plates are better off than stegosauruses without plates. Note the work that goes into this finding. First you have got to show that other options – defense – seem implausible. Second, you have got to show why your option is not just a fairly story. What critics of Darwinism call a "just-so" story (Gould and Lewontin 1979). In the paper referred to at the beginning of this essay, there is a lot of heavy-duty discussion about wind flow and the like. Of the three co-authors, only one was a paleontologist. His home was in the Division of Vertebrate Paleontology, Peabody Museum of Natural History, and Department of Geology and Geophysics, Yale University. The second was in the Department of Engineering and Applied Science, Yale University. The third was located in the Chemical Engineering Section, Department of Engineering and Applied Science, Yale University. A lot of hard work using nuts-and-bolts, non-biological science went into the arguments of this paper.

Notice what Darwin is doing, or rather what he is not doing. He is not denying teleology or explaining it away. He is offering final-cause explanations. The final cause of the plates on the back of the Stegosaurus is heat control. Behind this assumption or inference is the argumentation of Kant. The future tends to be like the past. Hence, because in the past the plates led to heat control, we assume that in the future they will lead to heat control. Sometimes this doesn't happen. That is the problem with rule of thumb explanations. But generally it does happen, or happen enough that organisms of this kind do get on to survive and reproduce, and that is enough. The future is not controlling the past. But we can expect that what has happened before will happen again, so we can use the expected future to explain what we have right now, today. Often, in the *Origin*, quite unselfconsciously, relying on this kind of reasoning, Darwin uses the language of final cause. Talking about embryological development.

> In certain cases the successive steps of variation might supervene, from causes of which we are wholly ignorant, at a very early period of life, or each step might be inherited at an earlier period than that at which it first appeared. In either case (as with the short-faced tumbler) the young or embryo would closely resemble the mature parent-form. We have seen that this is the rule of development in certain whole groups of animals, as with cuttle-fish and spiders, and with a few members of the great class of insects, as with Aphis. With respect to the final cause of the young in these cases not undergoing any metamorphosis, or closely resembling their parents from their earliest age, we can see that this would result from the two following contingencies; firstly, from the young, during a course of modification carried on for many generations, having to provide for their own wants at a very early stage of development, and secondly, from their following exactly the same habits of life with their parents; for in this case, it would be indispensable for the existence of the species, that the child should be modified at a very early age in the same manner with its parents, in accordance with their similar habits. (Darwin 1859, 448)

Aristotle would be proud of him!

So Darwin is offering final-cause explanations. He really is! Admittedly final cause explanations that conform to efficient-cause explanations, but real final-cause explanations for all that. What about the problems with these? Most obvious is one we have highlighted, the "missing goal object." I take the poison to kill myself but then you intervene and save me. No problem when you have consciousness involved. The efficient cause was my thought, my intention, to kill myself. I have that whether I follow through or not. But what about cases where no consciousness is involved? What about the plates along the back of the Stegosaurus? One thing you can be sure about is that it was not the mind of the Stegosaurus in play here. It had a brain about the size of a walnut, miniscule even by dinosaur standards. It had three ounces of grey matter to drive that five ton body. In the running for a Nobel Prize it was not. Plato says that God or the Form of the Good, the Demiurge, was doing it, so He (or It) had the thought in mind. The Demiurge was planning nice cool summers for the Stegosaurus, so even if the Stegosaurus doesn't get through Spring, the thought was there. Notice that here we have the notion of design. Plato thinks there was a Designer. Darwin as a scientist isn't going to commit himself on this one, but he does agree that organisms, inasmuch as they are adapted, are design-like. That is the whole point and why natural selection is needed. To a fellow scientist, in 1865 (six years after the publication of the *Origin*) Darwin wrote: "I believe we entirely agree that purpose or design is one of the surest & simplest roads to discovery in Natural History" (Darwin 1865). Some evolutionists of his day – famously his "bulldog" Thomas Henry Huxley – always preferred "saltationism," evolution by jumps – fox into dog in one generation. Darwin had no time for this. Jumps are random, and random means no design or appearance of design. In this sense, Darwin is 100% with Plato. And this is the reason why Darwin and his successors, including our Stegosaurus explainers, feel happy to draw analogies with machinery. Machinery is designed to have some end, some function, unlike random things put together like stones circling a finger at the end of a piece of string. Looking at the functions of machinery helps with the functions of organisms.

Aristotle says that it was some kind of force that is responsible for the plates. In some way, the Stegosaurus is directed towards a happy fulfilled life. One suggestion Aristotle makes (in *De Anima*) is that, in reproduction, although organisms do not become eternal, they get as close to the eternal as possible, and that in itself is a good. "The acts in which [the soul] manifests itself are reproduction and the use of food, because for any living thing that has reached its normal development . . . the most natural act is the production of another like itself, an animal producing an animal, a plant a plant, in order that, as far as nature allows, it may partake in the eternal and divine. That is the goal to which all things strive, that for the sake of which they do whatsoever their nature renders possible" (Barnes 1984, 661). I am not sure how keen Darwin would be on the "eternal and the divine." He certainly wouldn't want to bring it into his science. But he would be happy with the general idea, especially if the force is thought of less as a material thing and more as a

principle of organization. The whole point about adaptations is that they are organized, as if designed. They are not random, non-functioning, as you get from saltations. Darwin is not an Aristotelian but there is a family resemblance.

And so to Kant. Darwin agrees entirely with Kant that science cannot go outside law, unaided by God. Kant, was quite sure that there is a God involved – at the time of writing the *Origin*, Darwin probably thought so too – but Kant, and following him Darwin, was adamant that God had to stay outside science. In today's language, Kant and Darwin were "methodological naturalists," even though they might not have been "metaphysical naturalists." (It is plausible that Kant's thinking fed right through to Darwin. An important mentor of Darwin was the historian and philosopher of science, William Whewell. Although a strong Anglican – and hater of evolution – Whewell, who was a major Kantian, always kept religion out of science. His solution to the problem of organic origins was that of Boyle – whatever the origin, its understanding is outside science.) Darwin would agree also with Kant that final-cause thinking is invaluable from a heuristic standpoint. It is not just a prop for the inadequate. It is vital. You would never understand the plates on the back of the Stegosaurus unless you asked why they are there. Without asking that question, you wouldn't know about their existence, their nature (why, for instance, they are not made of the strongest possible materials – they don't need to be), their spacing, and much more. Where Darwin disagrees with Kant is in concluding that biology is second-rate. Darwin has given a fully adequate efficient cause for the plates and for other adaptations – or rather he has shown the way to giving explanations based on, and only on, efficient causes. It is just that, in the case of biology unlike the physical sciences, the subject matter is end-directed and that needs an explanation over and above the efficient-cause explanation.

What about value? The physical sciences don't generally talk about value. Saturn is not better than Jupiter. A cool planet is not better than a warm planet. It may be that we would prefer a cooler planet over a warmer planet, but that is our problem not that of science. It has no place for emotions. Knowledge without a knower. And yet here are our Stegosaurus researchers calmly telling us that the plates are of "value as convective heat loss fins." What is going on here? At this point it is important to distinguish between comparative value and absolute value (Nagel 1961). It is perfectly legitimate to talk in science about comparative value. One part or component of an existing machine does better than a proposed replacement. There is no real value in replacing what we have already. What is wrong in science is to talk about absolute value. As a scientist, you cannot say that global warming is a bad thing. You can say that if you continue to use fossil fuels at the rate we do, the planet will keep heating up and we will find it unpleasant. But that is us, not science. David Hume knew the score. Reason, which is what science is all about, is not the same as emotion, which is what our feeling of like and dislike, good

and evil, are all about. "It is not contrary to reason to prefer the destruction of the world to the scratching of my finger" (Hume 1739-1740, 415). You may be very sorry if you let it happen, but don't blame reason. Blame that itchy finger!

Darwin is not saying or implying that the Stegosaurus is better in some absolute sense than dinosaurs that don't have plates. He is simply saying that Stegos with plates do better than Stegos without plates. It is comparative value here not absolute value. I suspect that a lot of people might say that, in some absolute way, they prefer tigers over rats. But from an evolutionary point of view, rats do better than tigers. Apparently, their adaptations – like coming to fertility quickly, being able to adapt to circumstances quickly – are of more value to them, than the tigers' – being fierce and fast and fearless – are to them. Comparative value not absolute value.

Finally, let us take home an important philosophical message. As with students competing for prizes – for philosophers rising higher on various rankings devised by the web blog, *The Philosophical Gourmet* – areas of science compete for status. The sciences over the humanities, the humanities over the social sciences, everybody over education. Any reader of this article who does not agree that philosophers are the brightest people on campus is either abnormal or a liar. Among the sciences, we all know that physicists consider themselves the top dogs, with chemistry just behind, followed by molecular biology, and organismic biology – to which category the Stegosaurus study belongs – in last place. Even biologists can feel a bit that way, although then at once they turn round and console themselves that they are not sociologists.

All of this is harmless enough so long as it is confined to Friday night discussions in the faculty club. Where it goes wrong is when people start taking it seriously. There is a feeling that, unless in some way you can bring biology up to the standards of the physicists, it is forever doomed – and should get no more grants wasted on it. Perhaps best would be if biology could be reduced to physics, in the sense of being shown to be a deductive consequence of physics. Know your molecules. Know your Stegosauruses. Molecular biology is a good start. It is interesting that in their follow-up paper, Farlow and his fellow workers get right into "histology," defined by Meriam-Webster as "a branch of anatomy that deals with the minute structure of animal and plant tissues as discernible with the microscope." They cut up the plates and examined them under the microscope using all kinds of physical techniques involving lighting and the like, and they boiled their discussions down to issues amenable to physico-chemical understanding, like heat flow and transfer and the rates of liquid transmission through pipes (ferrying fluids of various temperature around the body) and so forth. They may not have been physicists, but they did their best!

Our discussions show that these dreams of reduction, specifically of biology to physics, the dream of the dominant philosophy of science known as "logical empiricism" and flourishing fifty years ago, are doomed to failure. Biology has, and demands, different

forms of explanation than physics and chemistry. This is not because it is second-rate but because it is different – it is explaining organized, end-directed entities, adaptations, of a kind unknown to the physical sciences. I doubt most people today would think they could reduce psychology to physics. Whatever is the nature of consciousness, only the crudest kind of materialist could think it is nothing but molecules in motion. The same is true of biology. So long as you have adaptations, you are going to need final causes. Physics doesn't need them. Biology does. That doesn't make biology second rate. Just different.

> Let us give our Stegosaurus authors the last word. Teleology is not about to vanish.
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> While more complete energy balance studies on Stegosaurus and its unfinned contemporaries might shed valuable additional light on questions of their climatic tolerances and extinction, we now believe that Stegosaurus's plates, because of their evidently efficient deployment as forced convective heat loss fins, constituted a physiologically effective thermoregulatory adaptation. (de Buffrénil, Farlow, and Ricqulès 1986, 473)

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