Teleology in Biology: Is it a Cause for Concern?

Michael Ruse

Evolutionary biology is distinctively forward looking or 'teleological' in its way of thought. In this, it distinguishes itself from the physical sciences. One can ask for the purpose *or* function *of the stegosaur's fins. One would never ask for the function of a planet. Many, including biologists, worry that such teleology is an unhappy legacy of a Christian past. Although teleology does have its roots in pre-evolutionary thought, there are good reasons why it has persisted, and there are equally good reasons why it should be cherished.*

Metaphors abound in evolutionary biology – as do their critics. For every evolutionist who happily distinguishes between *levels* of *selection*, who works out the mathematics of *adaptive landscapes*, or who traces the *tree* of life, there is a critic who grumbles that the *struggle* for existence is rarely a struggle or for existence[1], that natural *selection* is either tautological or theological[2,3], and that genes are never, ever *selfish*[4].

Prima facie this unease – specifically singling out evolutionary thought – seems misplaced and unfair. Physicists are just as free with their metaphors as are biologists. Such hallowed notions as force, work, power, attraction, all had their beginnings in metaphoric transference from the world of human thought and action. Yet it is not difficult to see a major reason why evolutionary thought and language disturbs. Unlike the world of the physical scientist, the world of the evolutionist is thoroughly drenched in the anthropomorphism of intention[5]. It is true that in the 19th century Sir David Brewster suggested that the moon exists *in order* to light the way home of lonely travellers[6], but no physicist would use such language today. In biology, however, especially evolutionary biology, this kind of talk is commonplace. One asks about the *purpose* of the fins on the back of Stegosaurus[7], one delves into the *function* of the bird's feathers[8], and depending on one's sources one learns that the Irish elk's antlers did or did not exist *in order* to intimidate rivals[9].

Why does this forward-looking, 'teleological' language bother anyone? Even biologists are troubled[10], to the extent that they often try to hide their thought behind new language like 'teleonomy'[11]. The American philosopher Ernest Nagel[12] pinpointed one of the most unfortunate implications, namely that of the 'missing goal-object'. Suppose you hear a sharp sound and want to find out the cause. If I tell you it was a banging door, then there is an end to it. The door banged. You heard the sound. Suppose now you want to know why men have testicles and I give you the (correct) answer that males have testicles *in order* to reproduce, or testicles serve the *end* of reproduction. But consider the case of two identical twin Catholic brothers, one of whom becomes a priest and the other a father of eight. Surely you want to say that their testicles have the same or identical causes, yet how can you say that they exist in order to reproduce when the one brother remains celibate and his testicles never lead to offspring?

Apparently there is something rotten here. With teleology, precisely because it is forward looking, the missing cause is always a possibility. The function might go unfulfilled[13]. This, of course, raises a question. Assuming for the moment that the critics' point is well-taken, why does biology embed a mode of thought that leads to such paradoxes? The answer, as so often happens, lies with the Greeks. It was they who set the whole of science off on a teleological mode, a mode from which physics escaped in the 16th and 17th centuries but which apparently still plagues biology[14].

In fact, there were two strands of teleology, both of which persisted for many years[15]. First, there was the Platonic 'external' version of teleology. Going back to the *Timaeus*, the world – the organic world particularly – is seen as an objective of design, namely God's design. For this reason, organisms look like artifacts, and for this reason (in the opinion of the Platonist) forward-looking language is appropriate[16]. Artifacts do have goals and ends: you can ask what the telescope is for, and you can likewise ask what the eye is for.

Secondly, there was the Aristotelian 'internal' version of teleology. Going back to *De Anima*, the world – the organic world particularly – is seen as being infused with spirit or 'soul'. This life force, or rather the individual life forces of individual organisms, seek out ends, just as do conscious human beings. Hence, for this reason (in the opinion of the Aristotelian) teleological language about strategies and so forth is entirely appropriate[17].

At once, argue the critics, we see that teleology is an unfortunate vestige of our past. Countering external teleology, for all that 18th century natural theologians like Archdeacon Paley[18] thought God designed the living world, Charles Darwin showed in the *Origin of Species*[19] that all is the end result of a slow process of evolution, primarily through the causal agency of natural selection. Countering internal teleology, for all that 20th century 'vitalists' like Hans Driesch[20] and Henri Bergson[21] have given organisms life forces – 'entelchies' or *'elans vitaux'* – mechanists down to today's molecular biologists have shown that life consists of inorganic building blocks, no more and no less[22].

It is the conclusion of such critics, therefore, that teleology should be eliminated.

Modern analyses

Unfortunately, such biological house-cleaning has proven uncommonly difficult. Often, paradoxically, even the severest critics slip into teleological language 'for the sake of convenience'[23]. Perhaps, therefore, it is better to seek an up-dated, non-troublesome analysis of teleology – one that acknowledges a role for teleological thought, that allows function-talk, but that does not suffer from the ills of traditional positions.

In the opinion of many, it was developments in the last war that pointed the way forward. Given the growing success of cybernetics,

Michael Ruse is at the Dept of Philosophy, University of Guelph, Guelph, Ontario, Canada N1G 2W1.

they thought that the secret to teleology lies in the 'goal-directed' engines of destruction that the conflict had produced[24]. Consider a torpedo: it might be made simply to churn through the water, or it might be more sophisticated, programmed to respond to a moving target, correcting its path as appropriate. Surely here we have a kind of end fixation, yet with none of the conceptually unhealthy connotations of traditional teleology. Could this not be a model for organisms – a forward direction without either design or vital forces?

Biologists and philosophers alike endorsed this approach[12]. They argued that what made teleological language appropriate – although, admittedly, in traditional terms the understanding was quasi-teleological – was the fact that organisms, unlike inorganic objects, are goal-directed or 'directively organized'. Yet many, including the late C.H. Waddington[25], doubted that this approach was entirely on track. Properties akin to the directive organization of the torpedo are certainly generally, if not always, possessed by organisms. But is it these that one is talking about when one uses teleological language? Suppose one explains the colour of a bird in terms of mate attraction – the *purpose* of the bright feathers, etc. It may well be that the bird itself has a built-in flexibility – perhaps if one insect source dries up, it can switch to another. But the wing colour itself may be unchangeable. If it attracts a new predator, the bird might simply get eaten and become extinct, which all rather suggests that the goal-directedness of the bird is irrelevant to that which leads us to speak of wing colour in teleological terms[26,27].

As Waddington pointed out, the man's testicles and the bird's wing seem to be *adaptations*, whereas goal-directedness talks about adaptability[25]. Perhaps the clue to the use of teleological language lies in the former, not the latter. This would certainly fit well with history, for we know that Darwin – who was one of the worst offenders when it came to teleological terms – picked up on the significance of adaptations from Paley, who made them central to his theological perspective[28]. Perhaps, therefore, the teleological language of biology translates simply (in modern biology) into normal causal claims about natural selection. There is no need to worry about the unfulfilled function of the priest's testicles. They are the end-product of natural selection, just like his brother's. And, what this means simply is that those of the brothers' would-be ancestors who had bigger and better testicles survived and reproduced in life's struggles, and those that had not did not. Ancestors, testicles and struggle were all in the past. The missing-goal-object problem vanishes. Yet, at the same time we continue to highlight and provide understanding to that which so fascinated pre-evolutionary thinkers[29–31].

Implications and queries

It is an analysis along these lines that is today favoured by most philosophers and philosophically minded biologists[11,32]. They allow that teleology and its language has a place in biology, but they deny that this is troublesome. Teleology has shifted its meaning and focus from its pre-evolutionary form, and now indeed centres on the key mechanism of change. Nevertheless, the suggestion that the teleology of biology rests on adaptations produced by natural selection raises a number of questions, some of which must be raised and discussed.

First, even if we grant the key role of natural selection, why does the teleology persist? Why not speak simply of the *past* effects of natural selection, of the adaptations produced, and have done with it? Why continue with the forward-looking mode of thought? Are we not still saddled with an out-dated metaphor, namely the metaphor of design? We continue to think of organisms *as if* they were artifacts, even though we now know that they are not. It was appropriate, although mistaken, to use teleological language when we thought that God was the Designer. It is inappropriate and mistaken to use teleological language when we know that natural selection does the work – or so complains the critic.

There is probably no ultimate response to this objection – metaphors in the last resort are a matter of taste – but we can give good reasons why the design language has persisted. Organisms, unlike planets and particles, really *do* look as if they were designed. Organisms may not be God's artifacts – or if they are, even Christians now agree that they are so only at a distance – but they are artifact-like. The eye is like a telescope. The heart is like a pump. (So much so, in fact, that students have great difficulty in seeing that calling the heart a 'pump' is not strictly literal – at least, it was not when Harvey first did it.) Natural selection makes for organization and functioning. Hence, teleological language comes naturally[33].

Why natural selection makes organisms design-like is a much more difficult question to answer – at least, it is if you take it in some ultimate sense and not as a specific question about a specific instance. Perhaps the 18th century (pre-evolutionary) Scottish philosopher David Hume[34] had correct insight. He pointed out that unless organisms were design-like, and that includes us, then nothing would work and there would be no one around to ask questions like: 'Why are organisms design-like?'. In other words, we have at work here a version of what cosmologists today call the 'anthropic principle'[35]. Things have to be as they are in order for us to ask the questions that we ask. Perhaps things could have been otherwise. Perhaps organisms did not have to be design-like. But then, we would never know.

A second question concerns the issue of translatability and reducibility. If the teleology of biology is really no more than talk about natural selection, how can the paradoxes like the missing-goal-object problem vanish? The answer, of course, is that we do not have a straight equivalence. Darwin's *Origin* meant something new for biology, even if much of the language stayed the same. If you think that butterflies' wings really are the end result of selection, this would have to have some consequences you would not expect were they the miraculous direct product of a designing God. Indeed you even expect some empirical differences, because God is perfect whereas selection is happy with less-than-best, so long as it is not second-best[36].

Nevertheless, the link between Darwinian teleology and post-Darwinian teleology is conceptually stronger than many realize. In an adaptationist argument, just like a natural theological argument, you are trying to *understand* in terms of what you think *will* generally happen[14,31]. The priest's testicles do have a function, even if he never exercises it. There is no attempt at a causal explanation from the future. For this reason, as we have seen, the missing goal-object is no longer a problem. Yet, in the present as in the past, there is a temporally atypical structure to understanding. You may put adaptations down to past causes, but you try to understand them in terms of what you think they *will* do, or what they could do, if given the chance. Your judgement is based on the past, but your commitment is to the future[27]. Of course, you may be wrong; but that is a risk that every scientist runs.

Third, what of the distinction between Plato and Aristotle? Neither was an evolutionist, yet both were responding sensitively to the organic world, as they saw it. If we grant what has been argued thus far, that teleology centres on the design-like effects of natural selection, we seem to have here a modern-day successor to Platonism. Do we likewise have a modern-day successor to Aristotelianism, a kind of seeking of ends yet without recourse to vital forces?

Such goal-orientation certainly sounds very close to those directively organized systems discussed earlier and much favoured at one point in analyses of teleology[12,24]. The teleology of Aristotle is akin to the adaptable aspects of nature, that thinkers like Nagel found distinctive of biological thought. This suggests that perhaps we were hasty in suggesting (or implying) that the true analysis of teleology had to be in terms of either directive organization or of the design-like effects of selection, but not both. Perhaps a more ecumenical position is more balanced, with scope for both neo-Platonism and neo-Aristotelianism.

This is a suggestion that is still controversial. Nevertheless, many would agree that if you have an artifact, then you must also allow the possibility of an artifact maker. Moreover, although the artifact has a fixed function, the maker (as a conscious being) has a flexibility of purpose, able to change ends or to persist to an end despite hurdles. Thus, inasmuch as we have consciousness, and (Descartes notwithstanding) most biologists today would admit at least some non-human animals to belong to this realm[37], we are forced to admit a teleology beyond that of simple adaptation[38]. Hence, the legacy of Aristotle does persist in modern biology alongside that of Plato. But, whether we should extend this alternative teleology down to all instances of goal-directedness including non-conscious manifestations like sweating and shivering is a moot point. All one can say is that some would and some would not allow such an extension, noting also that this division is what one expects when metaphors are at work.

Should we get rid of it?

One final question remains. Ultimately, everyone today will agree with critics of panadaptationism, like Stephen Jay Gould[39], when they complain that it is dreadfully easy to slip into assumptions of purpose when none exists. If God designed and if He is all-good and all-powerful, then we expect purpose in everything. If natural selection did the job or if something else was involved causally, we expect (as indeed we find) that many organic features have no purpose. Should we not, therefore, take heed of this warning and strive rigorously to eliminate all teleology from biology?

The proper response at this point surely counsels moderation. Being sensible about teleology is one thing. Rejecting it entirely is quite another. Like all metaphors, the artifact metaphor – to think now just of the successor to Platonic teleology – has incredible heuristic value[23]. If you think of features as objects of design, this stretches you to think about the specific purposes. You ask questions and you get answers you would never get were you not thinking this way. Why does the stegosaur have fins on its back, and why are they the peculiar diamond shape that they are[7]? They look remarkably like the blades one sees in hydro-electric plant turbos, designed for cooling. Could the fins be serving the same ends? Independent evidence towards which you are directed strongly suggests that this is so. Hence, the questions are asked and the answers given, and biological understanding moves forward.

What is really remarkable is the fate of teleology as the physical sciences have moved into biological domains. We find that molecular biology is as teleological as old-fashioned morphology. Molecular biologists talk confidently of genetic 'codes' and of their skill at 'cracking' them[40]. This is neo-Platonism triumphant. Perhaps, logically, in the interests of conceptual purity, one might eliminate the teleology of biology. However, one would thereby eliminate much of the fertility of biology. In respects, biology is not like physics and chemistry – nor should it strive to be.

References

1 Allen, E. *et al.* (1977) in *Biology as a Social Weapon* (Sociobiology Study Group of Boston, ed.), pp. 133–149, Burgess
2 Popper, K.R. (1974) *Unended Quest*, Open Court (pp. 167–179)
3 Young, R.M. (1985) *Darwin's Metaphor*, Cambridge University Press
4 Midgley, M. (1985) *Evolution as a Religion*, Methuen
5 Dennett, D. (1983) *Behav. Brain Sci.* 6, 343–390
6 Brewster, D. (1854) *More Worlds than One*, Murray
7 Lewontin, R.C. (1978) *Sci. Am.* 239(3), 212–230
8 Feduccia, A. (1980) *The Age of Birds*, Harvard University Press
9 Gould, S.J. (1973) *Nature* 104, 375–376
10 Kramer, P.J. (1984) *BioScience* 34, 405
11 Mayr, E. (1974) in *Boston Studies in the Philosophy of Science* XIV (Cohen, R.S. and Wartofsky, M.W. eds), pp. 91–117, Reidel
12 Nagel, E. (1961) *The Structure of Science*, Routledge & Kegan Paul
13 Mackie, J.L. (1966) *Philos. Rev.* 75, 441–466
14 Beckner, M. (1959) *The Biological Way of Thought*, Columbia University Press
15 Hull, D. (1973) *Darwin and His Critics*, Harvard University Press
16 Mayr, E. (1982) *The Growth of Biological Thought*, Harvard University Press
17 Gotthelf, A. and Lennox, J., eds (1987) *Philosophical Issues in Aristotle's Biology*, Cambridge University Press
18 Paley, W. (1802) *Natural Theology*, Rivington
19 Darwin, C. (1859) *On the Origin of Species*, Murray
20 Driesch, H. (1914) *The History and Theory of Vitalism*, London
21 Bergson, H. (1913) *Creative Evolution*, Macmillan

22 Rosenberg, A. (1985) *The Structure of Biological Science*, Cambridge University Press
23 Dobzhansky, T., Ayala, F.J., Stebbins, G.L. and Valentine, J.W. (1977) *Evolution*, Freeman
24 Sommerhoff, G. (1950) *Analytical Biology*, Oxford University Press
25 Waddington, C.H. (1957) *The Strategy of the Genes*, Allen & Unwin
26 Ruse, M. (1973) *The Philosophy of Biology*, Hutchinson
27 Woodfield, A. (1976) *Teleology*, Cambridge University Press
28 Ruse, M. (1979) *The Darwinian Revolution: Science Red in Tooth and Claw*, University of Chicago Press
29 Wright, L. (1976) *Teleological Explanations*, University of California Press
30 Wimsatt, W. (1972) *Stud. Hist. Philos. Sci.* 3, 1–80
31 Brandon, R.N. (1978) *Stud. Hist. Philos. Sci.* 9, 181–206
32 Hull, D.L. (1974) *Philosophy of Biological Science*, Prentice-Hall
33 Ruse, M. (1977) in *Logic, Laws, and Life* (Colodny, R., ed.) pp. 89–127, University of Pittsburgh Press
34 Hume, D. (1779) *Dialogues Concerning Natural Religion*, London
35 Barrow, J. and Tipler, F. (1986) *The Anthropic Cosmological Principle*, Oxford University Press
36 Sober, E. (1984) *The Nature of Selection: Evolutionary Theory in Philosophical Focus*, MIT Press
37 Walker, S. (1982) *Animal Thought*, Routledge & Kegan Paul
38 de Waal, F. (1982) *Chimpanzee Politics*, Cape
39 Gould, S.J. (1982) *Science* 216, 380–387
40 Ayala, F.J. and Kiger, J. (1984) *Modern Genetics* (2nd edn), Addison-Wesley

Does Copulation Increase the Risk of Predation?

Darryl T. Gwynne

Studies of mating behaviour have assumed that individuals are at greater risk when paired than when engaged in other activities. Recently, four experimental studies of insects and crustaceans have tested this assumption using predators from divergent taxa. Three of these studies indicate that mating carries no additional risk to the participants. Indeed, the findings suggest decreased vulnerability, relative to other activities, due to decreased predation on one or the other of the mating pair.

In a recent newspaper column[1], psychologist Dr A. Rincover asserted that 'in an evolutionary sense premature ejaculation had survival value. Animals were vulnerable to a surprise attack when copulating, therefore, the quicker an orgasm was achieved the better'. Although probably rare in discussions of sexual dysfunction, the reference to the vulnerability of copulating animals echoes a common assumption in behavioural ecology. It has been suggested that paired individuals could gain from an 'alliance' of defensive mechanisms[2,3] but, in general, studies of animal reproductive behaviour have assumed that copulation carries more risk than benefit (see, for example, Refs 4–8). The apparent reasoning is that the mating pair may be more conspicuous, less aware of their surrounding environment, or that physical connection during pairing or copulation results in a decrease in the opportunity for escape when a predatory attack occurs.

Darryl Gwynne is at the Zoology Dept, Erindale Campus, University of Toronto, Mississauga, Ontario L5L 1C6, Canada.

In his classic paper of 1927 on sexual selection, O.W. Richards[9] appears to have been one of the first to publish this suggestion. More recently, in a review in 1978 of the costs of mating behaviour, Daly[10] pointed out the likely risks associated with mating as well as the fact that this was a testable hypothesis with (at that time) little data to support it.

In this commentary I use the term *mating* in referring specifically to physical pairing. This includes both physical grasping of the mate and copulation *per se*. Solitary activities such as the mate-locating behaviour of males are thus excluded (the latter sort of behaviour has also been suggested to increase the risk of predation[11] and this has been confirmed by substantial empirical study: see Refs 12–14 for reviews).

Testing the assumption that mating is risky

Table 1 summarizes four recent studies which have tested the argument that mating individuals are more vulnerable to predation than unpaired individuals. The only study to support the hypothesis that pairs are preyed upon more than individuals is that of Ward[15] in which an amphipod crustacean was subjected to predation by fish. Predation rates on solitary males and pairs in precopula were compared. The latter were eaten more frequently (both members of the pair appeared to be consumed). No data were presented for predation on solitary females.

The remaining three studies do not support the mating-risk hypothesis; none showed increased predation on either member of the mating pair (Table 1). Moreover, the results showed that either the male or female may actually gain from a reduced risk of predation while paired. In a study of birds attacking stick insects, Sivinski[3] compared frequencies of predation on single individuals to that on mating pairs. In contrast to the amphipod study, males and females were rarely both killed during an attack. Sivinski's results showed significantly higher survival among copulating than solitary insects. When the data were analysed by sex it was found that females had a reduced probability of predation while mating but that there was no significant difference in predation on the two classes of males. Sivinski also found no difference in the percentage of solitary males and females taken by predators.

The results obtained in the remaining two studies, by Verrell[16] and McCauley and Lawson[17], were very similar to each other. In both studies predation rates on single males and females were compared to those on paired individuals. For reduviid bugs preying on beetles and newts preying on isopods, single males were more likely to be eaten than either single females or paired individuals of both sexes (predation rates on the last three groups were not significantly different).

Possible causes of a survival advantage while mating

What are the mechanisms that may have caused female stick insects and males of the beetle and isopod to experience a relative increase in survival while mating? Female stick insects may be more likely to survive an attack because of the vulnerable dorsal position of the mating male. Decreased risk *per se* could be due to the summed defensive mechanisms of the mating stick insects deterring attacks[2,3]. Sivinski[3]