

JETTISON THE ARGUMENTS, OR THE RULE? THE PLACE OF DARWINIAN THEOLOGICAL THEMATA IN EVOLUTIONARY REASONING

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1. INTRODUCTION

"No biologist today," observes Douglas Futuyma, "would think of submitting a paper entitled 'New evidence for evolution;' it simply has not been an issue for a century." [1] Whether they see it as an issue or not, however, biologists today still explain (in textbooks, for instance) why they think evolution is true. In other words, they regularly make a case for the theory.

On these occasions, an odd thing often happens. While presenting a line of evidence or argument for evolution, the author will, as a premise of his argument, make a theological claim. The case for evolution, in short, takes an unmistakably theological turn.

In their biology textbook *_A View of Life_*, for instance, Salvador Luria, Stephen Jay Gould, and Sam Singer argue as follows:

A whale's flipper, a man's arm, a bird's wing, and a dog's foreleg...perform functions about as different and varied as styles of locomotion in vertebrates can be, yet all are built of the same bones. Why would God have used the same building blocks, and distorted and twisted them in such odd ways, if He had simply set out to make the best swimming, running, and flying machines? The common structure must reflect common descent from an ancestor possessing these bones. [2]

Consider two other examples, drawn in both cases from the technical literature, where the theology is implicit under the rubric of "intelligent design" -- as expressed, for instance, by George Williams on the vertebrate retina:

...the optic nerve aris[es] on the wrong side of the sensory layer so that it must go through a hole in the retina to get to the brain. The diameter of the nerve is far greater than that of any retinal blood vessel. That means a large hole, and wherever it is there will be no vision. This is the reason for the blind spot, about 30 degrees right of the point of focus in the right eye, 30 degrees to the left in the left...

There would be no blind spot if the vertebrate eye were really intelligently designed. In fact it is stupidly designed, because it embodies many functionally arbitrary or maladaptive features, of which the inversion of the retina is merely one example. These features are there, not for functional but for purely historical reasons. [3]

Or consider Bruce Alberts on protein synthesis and ribosomes:

...the mechanism of protein synthesis seems complex and awkward compared to other biological processes that evolved later and were therefore based on protein catalysis....In other words, cells -- unlike computers -- are not optimally designed. Instead what they are today is in large part a reflection of their past history (Jacob, 1977). The ribosome is a notable example. As a machine for making proteins, the ribosome seems so awkward as to be a bore both for teachers to teach and for students to learn. Its many pieces seem to make no conceptual sense at all, especially when compared to the elegantly-designed pieces of a DNA replication machine....Only when viewed as a historical relic does the ribosome come alive. [4]

Now all this might be of little moment, were it not that these arguments sit uncomfortably with a widely advocated philosophical doctrine. It is generally held that evolutionary theory, like other natural sciences, employs necessarily a methodology according to which one cannot in scientific reasoning refer to "God," "the Creator," "creation" (understood as the act of a divine intelligence), or other theological concepts. Evolutionary biologists cite a variety of arguments in support of this view, or argue that in all events **methodological naturalism** (as the view has come to be known) stands very much at the foundation of the modern scientific outlook. [5]

Thus it is a point of considerable interest that, while presenting the "fact" of evolution (in writing introductory textbooks or encyclopedia articles, for instance), or in reasoning about organisms generally, many evolutionary biologists appeal to theology, or to aesthetic and teleological judgments (e.g., "optimal design," where the designing cause is an optimally acting and all-knowing intelligence) functionally indistinguishable from theology. This is noteworthy on at least two counts.

First, the demonstrable role of theology in evolutionary explanation provides evidence (or counterarguments) against the soundness of the philosophical doctrine of methodological naturalism. Methodological naturalism has lately come under critical scrutiny. [6] This essay provides some raw materials for that project, by showing how theological premises bear directly on the content of evolutionary explanations.

Secondly, this essay suggests that the received understanding of such questions as the significance of homologous patterns may be skewed by unjustified theological premises. In arguing for evolution, and in explaining the patterns of natural history, biologists have grown accustomed to making claims about what a creator would or would not have done. For this practice, they have the example of the *_Origin of Species_* itself, and indeed, Darwin's writings generally, where arguments of the sort at issue play an important role in the case for evolution.

We do not inherit a theology, however, as we do our hair color. We should adopt, or reject it, in terms of its coherence and correspondence with truth -- especially, for biologists, where that theology bears directly on one's understanding of the natural world.

2. THE IMPERFECTION ARGUMENT

In his *_History of Creation_*, Ernst Haeckel argued that "even if we knew absolutely nothing of the other phenomena of development, we should be obliged to believe in the truth of the Theory

of Descent, solely on the ground of the existence of rudimentary organs." [7] Under the heading of "Dysteleology," Haeckel gathered a number of apparently useless or imperfect structures that, he argued, could be reconciled with the theory of creation only by "ludicrous" ad hoc conjectures. In laying great stress on the evidential force of imperfection, Haeckel followed Darwin's lead. Throughout his entire corpus, Darwin is never stronger or more bitter in his language than when condemning the failed teleology of theories of creation, which impute imperfect organic design to the direct intent of a rational and benevolent creator.

Many current evolutionists stand squarely in this tradition. Arguments that trade on intuitions about the nature of God -- namely, that from his wisdom and perfection he would create only optimal or perfect designs -- occur widely in the recent evolutionary literature, in a variety of contexts. [8] Doubtless the most influential formulations, however, occur in the writings of Stephen Jay Gould. Since many authors draw on Gould's formulations, I will consider them here in detail (although, as noted, the same argument -- varying only in the particular organic design being considered -- is made by many others).

The following passages are all drawn from Gould's writings. While not structured formally as a series of premises leading to a conclusion, each passage does contain the elements of the argument, and expresses it either implicitly or explicitly.

The theory of natural selection would never have replaced the doctrine of divine creation if evident, admirable design pervaded all organisms. Charles Darwin understood this, and he focused on features that would be out of place in a world constructed by perfect wisdom. ... Darwin even wrote an entire book on orchids to argue that the structures evolved to ensure fertilization by insects are jerry-built of available parts used by ancestors for other purposes. Orchids are Rube Goldberg machines; a perfect engineer would certainly have come up with something better. This principle remains true today. The best illustrations of adaptation by evolution are the ones that strike our intuition as peculiar or bizarre. [9]

Odd arrangements and funny solutions are the proof of evolution -- paths that a sensible God would never tread but that a natural process, constrained by history, follows perforce. [10]

The proof that evolution, and not the fiat of a rational agent, has built organisms lies in the imperfections that record a history of descent and refute creation from nothing. ... Adaptation does not follow the blueprints of a perfect engineer. [11]

Evolution lies exposed in the imperfections that record a history of descent. Why should a rat run, a bat fly, a porpoise swim, and I type this essay with structures built of the same bones unless we all inherited them from a common ancestor? An engineer, starting from scratch, could design better limbs in each case. [12]

But how can a scientist infer history from single objects? This most common of historical dilemmas has a somewhat paradoxical solution. Darwin answers that we must look for imperfections and oddities, because any perfection in organic design or ecology obliterates the paths of history and might have been created as we find it. This principle of imperfection became Darwin's most common guide. ... I like to call it the "panda principle" in honor of my favorite example -- the highly inefficient, but serviceable, false thumb of the panda. [13]

It will be useful to formalize Gould's argument. I have drawn the following premises from the cited passages.

1. If p is an instance of organic design, then p was produced either by a wise creator, or by descent with modification (evolution).
2. If p (an instance of organic design) was produced by a wise creator, then p should be perfect (or should exhibit no imperfections).
3. Organic design p is not perfect (or exhibits imperfections).

From these premises, the conclusion follows that

Organic design p was not produced by a wise creator, but by descent with modification. Some organic designs are evidence of evolution.

Note that premises 1 and 2 are theological; they refer directly to a creator, and the actions expected of him. Gould's terms for the creator include "a perfect engineer," "a sensible God," "a rational agent," and "a wise creator." Note further that premises 2 and 3 refer to "perfection," and we may reasonably infer from the cited passages that Gould holds that humans can readily discern the presence or absence of perfection when they examine organic designs.

The conclusion requires of course both that perfection and imperfection be patent qualities of organic design, and that a wise creator would only create perfect organic designs. If these premises are granted, it will follow that any imperfect organic design is not the product of a wise creator. Rather it has come to be via the historically contingent processes of descent with modification.

And, according to Gould, examples of imperfect organic design abound. He writes of "vestigial organs," "odd biogeographic distributions made sensible only as products of history," and "adaptations as contrivances jury-rigged from parts available" [14] -- all of which, on the imperfection argument, provide evidence for descent.

3. SOME PROBLEMS WITH THE IMPERFECTION ARGUMENT

The imperfection argument for evolution is popular and compelling. It draws on widely shared intuitions about God and the nature and history of the structure of organisms. Discussing the argument with philosophers and biologists, I was struck by how many of them accepted it unreservedly as an impeccable piece of scientific reasoning.

Despite its wide appeal, however, the argument is also deeply problematical. The argument employs theological concepts, such as "a wise creator," and aesthetic or teleological notions, "perfection" and "imperfection," that cannot perform the analytical and empirical work required of them. Each premise of the argument is attended with difficulties.

A. Premise 1: "If p is an instance of organic design, then p was produced either by a wise creator, or by descent with modification."

In this section, I will assume that the concept "wise creator" and our ordinary notions of biological perfection and imperfection are unambiguous, that is, they are understood in the same way by all observers (assumptions which will be at issue below). I want first to examine a lesser difficulty, namely, that given our ordinary notions, the first premise of the imperfection argument is a false dichotomy.

The imperfection argument presupposes a static theory of creation, according to which an organic design p appears today largely as it was originally created. Yet few if any creationists would defend such a theory. [15] In fact, they are likely to acknowledge that some organic designs are biologically "imperfect," but will argue that such imperfection is consistent with their theoretical outlook. Not all "imperfections," therefore, would count against the theory of special creation, or a discontinuous geometry of organic form, as these structures would be expected under what might be called a "dynamic" theory of creation. In such cases the argument from divine wisdom will fail to hit its mark.

As an example, consider blind cave animals. Futuyma presents the functionless lens and retina of the cave salamander as instances of the imperfect workings of evolution. He then asks, "Do we find evidence here of wise design?" [16] Yet in the same year that Futuyma posed his question, two well-known creationists, independently considering the same phenomenon, saw it as degenerative change easily understood under a creation theory:

Blind cave fish with remnants of eyes...appear to have true vestigial organs. These and similar degenerations apparently have indeed resulted from typically disadvantageous mutations....When hereditary changes are small enough to permit survival and reproduction, vestiges may remain. However, these vestigial structures at best are indicative of changes within limits; they are usually degenerative changes within a species. [17]

So Futuyma's question has answers other than the one he presupposes. In all likelihood the apparently poor design of the cave salamander's eye is the consequence of evolutionary change, but such degenerative changes can readily be accommodated within a dynamic theory of creation.

Consider another example, the rudimentary wings of flightless birds, which Naylor regards as true vestigial structures whose existence contradicts the theory of creation. [18] The Dutch creationist Hendrik Murriss, however, in a discussion of genetic drift and the limits of variation, argues:

Suppose that (as an oversimplified example) the allele 'A' imparts the ability to fly, while 'a' signifies flightlessness. If birds with AA and Aa combinations arrive and breed on an island where they have no natural enemies, the flightless aa individuals which will inevitably be hatched will survive. Some generations later, according to our model experiment, the entire population could be flightless! [19]

Murriss goes on to argue that within the theory of creation, known genetic processes may explain the origin of some, though not all, species of flightless birds. In a related analysis, the German creationists Reinhard Junker and Siegfried Scherer explain the origin of the rudimentary wings of flightless beetles and insects as cases of degenerative microevolution. [20] Junker later authored a systematic treatment of rudimentary organs and atavisms within a creationist framework. [21] In these dynamic theories of creation, extant organic designs are the products not just of original creative intent, but also of the perturbing effects of secondary causes, e.g., natural selection, mutation, or genetic drift. [22] Thus, in any assessment of the optimality of an organic design, the perturbing effects of secondary and natural causes must be separated from original design (if such a historical reconstruction is possible).

By presupposing a static theory of creation, the first premise of the argument from divine wisdom describes a false dichotomy. Of course, many supposedly imperfect organic designs, such as human upright posture, or the human retina, cannot be explained by a dynamic theory of

creation as the consequence of simple degenerative changes. A dynamic theory of creation can accommodate only certain limited neutral or degenerative changes without contradicting another of its main empirical tenets, namely, that genetic and phenotypic variation is bounded. Most "vestigial" structures, for instance, appear to mark out paths of phylogenetic branching that are expressly denied by even the most flexibly dynamic theories of creation. In any event, the argument from divine wisdom need not, indeed should not, presuppose a static theory of creation. That it does so often presuppose such a theory, however, should alert us to the possibility that the argument may rest on other problematical presuppositions.

B. Premise 2: "If p was produced by a wise creator, then p should be perfect (or exhibit no imperfections)."

With this premise, we come upon the major theological difficulties of the argument. In Gould's formulations, and in any formulation which includes statements about the character and actions of a "wise creator," the argument from divine wisdom makes theological claims which must be justified or explicated, irrespective of the argument's empirical content. The structure of the argument requires that "wise creator" be fixed objectively in some way. In other words, any exponent of the argument must explain (1) what a "wise creator" or a "sensible God" is, and (2) what a "wise creator" would do.

To illustrate the first problem, assume for the moment that we are able to identify an imperfect organic design p. Then suppose our conception of the creator is similar to John Stuart Mill's: the creator is benevolent and wise but not omnipotent. [23] This creator's power is limited, and thus he would not be able to avoid occasional design compromises. Some imperfections would necessarily be included in the creation -- including, let us say, the imperfect organic design p. On this view of the creator, the conclusion that imperfection of organic design is evidence of descent with modification would not follow in every case. Gould writes that perfection alone cannot demonstrate descent, because "perfection need not have a history." [24] If we employ Mill's conception of the creator, however, imperfection need not have a history either. [25] If a stapler that continually jams or a water pitcher with a dribbling spout were designed de novo, they have no history in an evolutionary sense -- yet both artifacts are manifestly imperfect to anyone knowing their intended functions.

Mill's limited creator is heterodox (in the Christian tradition), and some may wish to argue that one either defends the usual omnipotent conception of the creator, or one defends no conception at all. The point however is that we have no grounds within evolutionary theory itself to exclude Mill's creator, or any one of a number of conceivable creators whose natures allow imperfection. The creator's place in the argument can't be filled by just any conception. [26] To sustain the conclusion, "Imperfection of organic design is evidence of descent," the argument from divine wisdom requires a particular conception of the creator, namely, the conventional picture of an omnipotent and beneficent artificer (hereafter, the conventional conception). Thus, far from being theologically neutral, the argument has a stake in the truth of a particular theology.

I turn next to the problem of what a "wise creator" would do, a problem related to the ambiguity of "perfection" as an operational construct. Suppose we begin with the conventional conception of the creator. According to the second premise of the argument from divine wisdom, if a perfect God created the world, we should expect to observe "perfect" organic design -- but what sense should be attached to this term? Is it possible that biological entities judged imperfect when considered individually, might combine to form a macrosystem judged perfect? Here, theological

difficulties ordinarily ignored in any biological analysis come crowding to the fore. These difficulties can be avoided only by stipulation.

Consider, for instance, the question of the creator's proper domain. Many philosophers and theologians take the creator's proper domain to be the entirety of time and space, and furthermore hold that issues of moral value figure ultimately in any theory of creation. If this is so then the finitude of human scientific observation may lead us to infer mistakenly that an organic design (e.g., the panda's pseudthumb) is imperfect, when its imperfection is only apparent, that is, local. On this view, any judgment of perfection or imperfection must be qualified with a proviso that perfection -- defined as divinely created perfection -- can be judged only on the scale of the whole creation. And there is no reason for a creator to optimize one part of the universe at the expense of the whole.

As one commentator writes:

According to this view, what appears to be evil, when seen in isolation or in a too limited context, is a necessary element in a universe which, viewed as a totality, is wholly good. From the viewpoint of God, who sees timelessly and as a whole the entire moving panorama of created history, the universe is good....[27]

Several philosophers have articulated theodicies which employ just such an analysis; Augustine and Leibniz are notable examples. [28] In his Theodicy, Leibniz argued:

[W]e acknowledge...that God does all the best possible, in accordance with the infinite wisdom which guides his actions...But when we see some broken bone, some piece of animal's flesh, some sprig of a plant, there appears to be nothing but confusion, unless an excellent anatomist observe it: and even he would recognize nothing therein if he had not seen like pieces attached to their whole. It is the same with the government of God: that which we have been able to see hitherto is not a large enough piece for recognition of the beauty and order of the whole. [29]

Although one may regard such a theodicy with skepticism (or scorn: see *Candide*), the problem remains. How is one to judge divine perfection? The question cannot be evaded, for the argument itself demands an answer. To be sure, one can stipulate that only matters of biological optimality are relevant. The stipulation, however, is entirely arbitrary.

My intention here should not be mistaken. I am not defending a Leibnizian theodicy, but want only to stress that the "wise creator" of the argument from divine wisdom is hardly the plain and readily employed concept many take it to be. That these problems have been largely ignored by exponents of the argument should not be taken as evidence that they are insignificant.

C. Premise 3: "Organic design p is not perfect (or exhibits imperfections)."

All exponents of the argument from divine wisdom hold (either explicitly or implicitly) that perfection and imperfection are observable aspects of organic design. Gould writes of perfection as

the complex and perfected adaptations of organisms to their environments: the butterfly passing for a dead leaf, the bittern for a branch, the superb engineering of a gull aloft or a tuna in the sea. [30]

These admirable organic designs are contrasted by Gould with the imperfection of "[r]emnants of the past that don't make sense in present terms -- the useless, the odd, the peculiar, the incongruous." [31]

The terms "perfection" and "imperfection" have long been part of the descriptive vocabulary of natural history. We readily apply both to organic designs we admire or find puzzling (or repugnant). As a consequence many authors use the terms with little apparent reflection, perhaps thinking that, as operational constructs in biology, "perfection" and "imperfection" are entirely perspicuous. They are not. The epistemological difficulties that plague optimality arguments in evolutionary theory also occur in judgments of perfection (or imperfection). [32] In the latter case, however, the difficulty of determining whether a state of a trait or organism is optimal is magnified immeasurably by the theological context.

Recall that the second premise of the argument states that a "wise creator" will create perfect organic designs. This seems clear enough until we come to particular cases, such as the panda. Gould argues that we can use optimality theory to designate "ideals for assessing natural departures." [33] It follows that in finding existing pandas to be imperfect, Gould must have some notion of an ideal panda, departure from which evokes a judgment of imperfection. So what does an ideal panda look like?

That is rather hard to say, as Maynard Smith has pointed out:

It is clearly impossible to say what is the "best" phenotype unless one knows the range of possibilities. If there were no constraints on what is possible, the best phenotype would live for ever, would be impregnable to predators, would lay eggs at an infinite rate, and so on. It is therefore necessary to specify the set of possible phenotypes, or in some other way describe the limits on what can evolve. [34]

With the argument from divine wisdom, however, the question is not what can possibly evolve, but what can possibly be created. If we employ the conventional conception of the creator, there seem to be no limits on what is possible, nor any reason (short perhaps of logical contradiction) why one hypothetically possible panda should be preferred -- as a counterfactual ideal -- to another. If "perfection" is limited only by the extent of one's imagination, then specifying an ideal phenotype, for the panda or any other organism, quickly becomes a fanciful exercise. Why couldn't the creator have given pandas the ability to fly?

We might then turn the problem around, and define a criterion of optimality that a "wise creator" ought to be able to achieve. Real organisms, if they were specially created, should then measure up. The problem we hoped to escape, however, now returns in another form. Just as within evolutionary theory, "a proper optimization theory must be capable of explaining why particular constraints on [phenotypic] accessibility are regarded as absolute while others are not," [35] so the imperfection argument requires some intrinsic reasons why the creator's designs should be limited by physical or biological constraints in certain instances but not in others.

Take Gould's judgment that the panda's pseudthumb is suboptimal or imperfect, falling short of what we might expect of a "wise creator." Despite this judgment -- that the thumb is "somewhat clumsy" and "wins no prizes in an engineer's derby" [36] -- Gould writes that while watching pandas at the National Zoo in Washington, D.C., he was "amazed at their dexterity, and wondered how the scion of a stock adapted for running could use its hands so adroitly." [37] Other observers of the panda heap praise on its use of its forelimbs:

The panda can handle bamboo stems with great precision, by holding them as if with forceps in the hairless groove connecting the pad of the first digit and pseudthumb. [38]

When watching a panda eat leaves...we were always impressed by its dexterity. Forepaws and mouth work together with great precision, with great economy of motion....[39]

Although the panda's thumb may be suboptimal for many tasks (such as typing), it does seem suited for what appears to be its usual function, stripping bamboo. (At any rate the facts of the matter are very much in dispute.)

But even if the pseudthumb were suboptimal for stripping bamboo, it might still be the best structure possible. The creator could have been limited in some way by unknown "compossibility" constraints. In crudest outline, a compossibility analysis would ask whether all possibilities are mutually consistent. One cannot, for instance, expect an electric clock designed to obtain its regularity from alternating current to be more regular than that current. [40] Or the thumb may have some unknown primary function for which it was designed, and the panda has co-opted it secondarily to strip bamboo. One may have failed to identify the correct reference situation by which to judge the design (perhaps by looking at too narrow a slice of the panda's life history). The flippers of marine turtles, for example, strike us as rather badly designed for digging holes in beach sand to place eggs. The same flippers, however, perform efficiently in the water, where the turtles spend most of their time. Which reference situation takes precedence in an optimality analysis? [41]

If we allow that the creator need only "act reasonably," that is, create organic designs which meet some specific criteria for optimality, then we must be able to say what those criteria are, and why they obtain, if our claims of suboptimality or imperfection are to have any evidential force. This problem is made acute by the bothersome truth that any suboptimal design can be made optimal if specify the right constraints. [42] What principles, then, guide us in specifying reasonable criteria of optimality for an omnipotent creator?

A simple equation illustrates the problem. Suppose we define an optimal organism (design) as scoring 1.0, where the observed and expected design values in the following equation correspond exactly:

$$\frac{\text{observed design}}{\text{-----}} = \text{optimality (suboptimality) measure} \frac{\text{expected design}}{\text{-----}}$$

Now suboptimality enters in when the numerator value falls below that of the denominator. Thus, if an optimal (created or ideal) panda has an expected design value of, say, 50, but actual pandas score 30, the panda as a species is suboptimal, suffering what we might call a "design shortfall":

$$\frac{\text{observed design} - 30}{\text{-----}} = .6 \text{ design shortfall} \frac{\text{expected design} - 50}{\text{-----}}$$

We cannot solve this equation, however, without the expected design value. Absent the denominator, the equation has two unknowns and thus is unsolvable. [43] But the expected design must be determined by optimality criteria, a set of metrics along which design is measured -- and we have no such metrics for living things as divinely created. Thus we have no principled way of assigning the expected design value.

Evolutionists have learned to be wary of facile arguments about optimality and perfection within evolutionary theory. The divergence of views on the panda's pseudthumb, given above, is a good example of why they are wary. Gould finds the structure "somewhat clumsy," whereas Schaller et al. give it the precision of a "forceps." Would these investigators would differ so widely on the question of, say, the panda's diploid karyotype number?

In summary, the imperfection argument is deeply flawed. Gould repeatedly uses the word "proof" for the argument. That, it surely is not.

4. THE HOMOLOGY ARGUMENT

On opening any moderately advanced biology textbook nowadays one is likely to find, amid the discussion of the evidence for common descent, an illustration showing an array of tetrapod forelimbs. The text will state that the pattern of similarity abstracted from the limbs (the pentadactyl limb) can be explained only by common descent. Francisco Ayala, for instance, in his Encyclopedia Britannica article on evolution writes:

From a purely practical point of view, it is incomprehensible that a turtle should swim, a horse run, a person write, and a bird or bat fly with structures built of the same bones. An engineer could design better limbs in each case. But if it is accepted that all of these skeletons inherited their structures from a common ancestor and became modified only as they adapted to different ways of life, the similarity of their structures makes sense. [44]

"An engineer could design better limbs in each case" has the ring of an empirical finding. But the story is rather more complicated.

In Chapter XIII of the Origin, Darwin argued that it would be "hopeless" to explain the pentadactyl pattern "by utility or by the doctrine of final causes." [45]. As Cain observes, Darwin's view of these patterns is now canonical:

Darwin...originated the evolutionary interpretation which has been followed ever since, that the general plan of the pentadactyl limb is not now adaptive, although it must have been in the common ancestor, but its modifications are adaptive. [46]

But how do we know that the general plan is suboptimal? This claim, after all, drives the inference to descent, or, to put it another way, makes implausible the inference to an optimizing designer. (A designer may have used the same pattern in different organisms precisely because that pattern is optimal for the functions in question.) What, then, grounds this seemingly empirical determination of suboptimality?

Here a brief historical excursus will be helpful. The patterns of homology employed by Darwin were familiar to pre-Darwinian anatomists, having been worked out by them in a non-evolutionary context. "Pre-Darwinian systematics did not profess an evolutionary explanation for homology," writes Ronald Brady, "but that privation did not prevent an extensive investigation of comparative anatomy, during which the principles of systematics were developed." [47]

Although the "unity of plan" of the tetrapod forelimb was powerfully suggestive of descent, and was so seen by some pre-Darwinians, descent was far from being the only plausible causal account available. [48] The patterns of similarity evident among major groups of animals suggested similar functional requirements (Cuvier), non-material archetypes (Owen), or the plan of the Creator (Agassiz). Without transitional forms or a mechanism of functional transformation, non-material causes were genuinely competing explanations. [49]

Darwin made the patterns themselves the puzzle. Common descent would become the only reasonable explanation if Darwin's readers could be persuaded that, even without other "facts or arguments" [50] for descent, the theory explained patterns before which rival theories stood silent. But the rival theories -- in particular, creation -- must in fact stand silent, for if they also explained the patterns at hand, descent might remain only a plausible but unconvincing theory, unable to claim broader explanatory promise than its rivals.

In the Origin (especially Chapter XIII), therefore, Darwin frames the patterns of comparative natural history in terms favorable to common descent, but uncongenial to any non-material

explanation invoking design. In particular, one important avenue of explanation open to the creationist must be cut off, namely, the possibility that homologous patterns, such as the pentadactyl limb, are functionally optimal, and thus, could reasonably have been intended, and realized, by an optimizing creator.

For this task, Darwin finds a ready if unwitting ally in Owen. "What could be more curious," asks Darwin, "than that the hand of a man, formed for grasping, that of a mole for digging, the leg of the horse, the paddle of the porpoise, and the wing of the bat, should all be constructed on the same pattern, and should include the same bones, in the same relative positions?" [51] Four of the five examples given -- human hand, mole, horse, and bat -- are Owen's, from *On the Nature of Limbs*. (Darwin substitutes a more familiar creature, the porpoise, for Owen's example of an aquatic mammal, the dugong.) It would be "hopeless," Darwin warns, to explain this pattern of similarity by functional utility: "The hopelessness of the attempt has been expressly admitted by Owen in his most interesting work on the 'Nature of Limbs'." [52]

Now it appears from Darwin's phrasing ("expressly admitted") that Owen, having failed to show that the pentadactyl pattern was functionally useful, was conceding as much. But this is "seriously misleading in one respect," Cain notes. "The hopelessness of the attempt is not what Owen was driven by the facts to *admit*, but what his whole lecture set out enthusiastically to *proclaim*." [53] Owen was keen to refute the notion that the structures of organisms were specifically designed for their functions. He thus makes room for his "legitimate fruit of inductive research," namely, the "higher law of archetypal conformity." [54] In attacking the principle of specific design, and arguing for the constraints of archetypal homology, Owen cannot help supporting Darwin -- who understandably then calls on him as an anatomical authority favoring descent, Owen's qualms about that the naturalistic version of that theory notwithstanding.

One will search *On the Nature of Limbs* in vain, however, for anything resembling an empirical demonstration that an homologous plan limits functionality, thus rendering an organism suboptimal. Owen's argument rests, rather, on an a priori principle:

The teleologist would rather expect to find the same direct and purposive adaptation of the limb to its office as in the machine [devised by humans]. [55]

Given some functional end, the human engineer "does not fetter himself by the trammels of any common type," says Owen, but uses whatever design is best suited:

There is no community of plan or structure between the boat and the balloon, between Stephenson's locomotive engine and Brunel's tunneling machinery: a very remote analogy, if any, can be traced between the instruments devised by man to travel in the air and on the sea, through the earth or along its surface. [56]

Yet when we consider organismal structures, Owen argues, a remarkable "unity of plan" is found -- "so little to be expected, a priori":

That every segment and almost every bone which is present in the human hand and arm should exist in the fin of the whale, solely because it is assumed that they were required in such number and collocation for the support and movements of that undivided and inflexible paddle, *squares...little with our idea of the simplest mode of effecting the purpose*.... [57]

Richard Owen would have designed organisms differently. But of what evidential significance are Richard Owen's ideas about "the simplest mode of effecting the purpose"? We want to know

if the structures of animals are well-suited to the functions they must perform: a question to be answered -- if it can be answered at all -- on the grounds, not of any "deep and pregnant" a priori principle, but by observation and experiment.

Owen never demonstrates that the various mammalian forelimbs he has examined, constructed on a common plan, are functionally less than optimal for being so constructed. Yet this is what Darwin takes away from Owen, and that, in turn, evolutionary biologists have taken away from Darwin. "An engineer could design better limbs in each case." [58] There is no evidence that this is true.

What does ground the perception of suboptimality so widely shared among evolutionary biologists? Here, I would argue, strong theological preconceptions are at work. If we suppose that the creator is free to do as he pleases, the appearance of plan can readily become the appearance of limitation or constraint, suggesting an unimaginative or even slavish repetition of structures along the lines of some predetermined pattern. "Intelligence and purpose," writes Neal Gillespie, interpreting Darwin's arguments against creation, "should be more creative than nature showed itself to be." [59]

The theological premise in this argument -- that the apparent uniformity of certain biological patterns is inconsistent with the freedom of a creator to act as he wishes -- is nowhere better illustrated than in Darwin's book on the "contrivances" of orchids. After reviewing the homologies of orchids and ordinary flowers, Darwin appeals to our intuitions about what God would have done in this case:

Can we feel satisfied by saying that each Orchid was created, exactly as we now see it, on a certain "ideal type:" that the omnipotent Creator, having fixed on one plan for the whole Order, did not depart from this plan: that he, therefore, made the same organ to perform diverse functions -- often of trifling importance compared with their proper function -- converted other organs into mere purposeless rudiments, and arranged all as if they had to stand separate, and then made them cohere? Is it not a more simple and intelligible view that all the Orchideae owe what they have in common, to descent from some monocotyledonous plant....? [60]

Removing the theology from Darwin's argument for the common descent of the Orchideae would eviscerate it. Darwin provides no fossil evidence that orchids evolved from ordinary flowers, nor indeed any experimental evidence that such a transformation is even possible. [61] Rather, in the chapter leading to the passage cited above, Darwin describes patterns of similarity among orchids -- which patterns might, on a creationist reading of the evidence, indicate the purposeful workings of a designer. If one accepts however the premise that it is unfitting to ascribe variations on an "ideal type" to the direct artifice of an omnipotent creator, the same patterns become evidence of common descent. The theology in the passage is thus far more than a rhetorical device. It is the logical pivot of Darwin's entire argument.

Interestingly, Gould and other commentators (e.g., Michael Ghiselin [62]) have not noticed this problem. Perhaps Darwin's theological aesthetic is so closely congruent with their own intuitions that its role in the argument escapes comment. Nevertheless, these theological assumptions are critical to the conclusions Darwin hopes to draw from his botanical comparisons, as can be seen by inserting different assumptions into the argument. Why not suppose, for instance, that a divine artificer *would* have used homologies between flowers and orchids? In analyzing Darwin's argument about homologies -- in particular, his claim that a Creator would not use such patterns -- Lovtrup observes:

Why not? Even the Creator may use a good device more than once. Yes, why not indeed? Darwin's arguments against this possibility are postulates, unfounded by any evidence. [63]

Different theological postulates (i.e., other than Darwin's) would imperil his case for the common descent of the orchids. One can jettison the theology, but then the patterns of similarity remain only phenomena to be explained: they do not speak univocally for descent, as opposed to design or creation.

5. THE INFLUENCE OF DARWINIAN THEOLOGICAL METAPHYSICS

Darwin's argument for descent with modification was pressed on many fronts -- among them, the theological. As several historical and philosophical analyses of Darwin's corpus have noted, [64] the Notebooks, the Sketches of 1842 and 1844, and the *Origin* itself are permeated by a metaphysical program which was, Cornell argues, "more than useful rhetoric to Darwin, and more than a methodological convention that promoted science." [65]

Consider one important aspect of that program, the notion of "perfection." Dov Ospovat writes:

The assumption of perfect adaptation, which Darwin shared with most of the biologists of his generation, was derived from the belief that nature is a created, harmonious, and purposeful whole....This is the assumption...that organisms are as well fitted as possible for the conditions under which they live. This assumption, in one form or another, was held by virtually every naturalist and natural theologian of the mid-nineteenth century. It is a natural, perhaps necessary, corollary of the belief that nature is a harmonious system preplanned in every detail by a wise and benevolent God. [66]

Cornell concurs:

The word "perfect" is an adjective generally reserved for divine action. That is how, for instance, Paley used it, and it was probably what Darwin understood, even when he was criticizing the belief in the Perfection of particular forms...because that belief implied special creation by God. [67]

Now, while Darwin came to reject the idea that organisms were perfectly designed for their environments, he never rejected the theoretical apparatus implied by the very terms "perfection" and "imperfection." The numerous theological arguments in the *Origin* make sense only if one presupposes certain premises, about the Nature of the creator, from the classical argument from design. Darwin does not challenge the orthodox (or, in my term, conventional) conception of the creator, defended by his creationist opponents. Rather, he turns to certain aspects of organic design which appear to fit only awkwardly into the usual schemes of natural theology, and drives these organic counterexamples back into the machinery of the argument from design. Instead of impiously attacking the nature or existence of the creator (as a skeptic might do), Darwin offers his theory of descent (and secondary causes) to explain what would otherwise be intolerable anomalies. All this incongruity of design could not have been directly created.

In so doing, of course, Darwin impales his creationist opponents on the horns of a dilemma. Either they deny the benevolence and wisdom of the creator, by making him the author of "abhorrent" designs, or they retain their wise and benevolent conception of the creator, but must greatly circumscribe his actions, for if imperfect designs could be due to secondary causes, then

could not many other (in fact, nearly all) organic structures be the products of secondary causes as well?

But note again that in all this there is little to indicate that Darwin ever rejected the deep presuppositions which he inherited from English natural theology, namely, perfection as an observable quality of organic design, and the orthodox or conventional conception of the nature (if not the actions) of the creator. Indeed, a close reading of the Notebooks would seem to suggest that Darwin saw his theory as providing a more sublime conception of the actions of the creator (see, for instance, D 36: "What a magnificent view one can take of the world..."). Many passages in Darwin's corpus make little sense unless it is acknowledged that Darwin was employing a particular conception of the creator to judge the theories of his creative activity. Otherwise, why should the multiple creations scornfully derided in D 36 as a "long succession of vile molluscous animals" be beneath the "dignity" of God?

Cornell argues, of this and other passages from later notebooks:

As always, Darwin's idea of "perfection" refers to the nice relationship of organisms to their physical surroundings. But it also refers to the overall design of the world, from a divine viewpoint.... Darwin's sense of a comprehensive system, the invocation of divine perfection, and his new theory are thus all closely related. [68]

Brooke argues, in relation to these passages:

The fact is that there are several entries in the transmutation notebooks which indicate that Darwin was discovering a philosophy of nature which he genuinely believed conferred a new grandeur on the deity, despite -- or rather because of -- the fact that it superseded Paley. [69]

While current evolutionists may not share (or in fact may be opposed to) Darwin's theological motivations, their use of the imperfection and homology arguments for descent presupposes the intelligibility of notions rooted in Darwin's theological metaphysics. The notion of perfection as an observable quality of organic design, and the intuition lying at the heart of Darwin's metaphysics -- that a rational and benevolent God would have created an organic world different from the one we observe -- continue to inform the philosophical foundations of evolutionary theory (as should be evident from the passages I have cited from Gould above).

Yet it is widely held that an important aspect of the Darwinian revolution was the surrender, by biologists and natural historians, of any warrant to theological speculation in science. [70] Indeed, many scientists and philosophers would argue that natural science and theology view each other across a largely (if not completely) impassable epistemological gulf. [71] Science, on this view, is by its very nature committed to a thoroughgoing methodological naturalism. Hence, the problem which opened this essay: the persistence of Darwinian theological themata in current evolutionary theory is *prima facie* inconsistent with the doctrine of methodological naturalism.

Now, one might argue that the thrust of my essay supports the wisdom of the rule of methodological naturalism. "Get theology out of science" could be the take-home moral: theists, deists, agnostics, skeptics and atheists can all agree how to count fruit fly bristles, say, or how to calculate the distance to the sun. We cannot agree, even in principle (so the argument would run), on whether God would, or would not, create vertebrates according to homologous patterns; indeed it seems we cannot agree on anything God would have done. "No man hath seen God at any time." Obviously this creates problems for an empirical enterprise like natural science.

But nothing in what I have argued should be seen as a brief for methodological naturalism. It is possible that an intelligence created the world, just as it is possible that, to take the other (opposing) ancient hypothesis, the world contains its springs of order and design wholly within itself. Whatever philosophy of science we adopt should allow for both possibilities; methodological naturalism does not; therefore methodological naturalism is unsound.

The interaction of science and theology is difficult. That much should be plain. All the difference in the world exists, however, between a rational inquiry that is difficult and one that is in principle impossible. Unfortunately, evolutionary biologists stand in a confused tradition with regard to these questions. On one hand, as Ernst Mayr points out, Darwin himself was converted to his new ideas only after he had made numerous observations that were to him quite incompatible with creation. He felt strongly that he must establish this point decisively before his readers would be willing to listen to the evolutionary interpretation. Again and again, he describes phenomena that do not fit the creation theory. [72]

That the phenomena do not fit the creation theory implies of course that they might have fit. As it happens, they did not, and thus the theory of creation in question is false. It is, I think, impossible to understand "the long argument" of the *Origin* except in this light. Darwin was testing a theory of creation -- a process methodological naturalism holds to be in principle impossible. This historical evidence about the actual practice of science suggests that descriptively, at any rate, the thesis of methodological naturalism is going to fail badly.

On the other hand, Darwin also argued that theories of creation merely restate the facts to be explained "in dignified language," implying that such theories were sham explanations, saying nothing about the phenomena beyond "we can only say that so it is; -- that is has so pleased the Creator to construct each plant and animal." [73 And in later editions of the *Origin*, as David Hull points out, Darwin concluded his discussion of Owen's interpretation of homology by arguing "but this is not a scientific explanation." [74] On this view of the Darwinian Revolution, one for which there is powerful evidence, Darwin had the same opinion of all [theories of origin] but his own -- they were not 'scientific'....The Darwin revolution was as much concerned with the promotion of a particular view of science as it was with the introduction of a theory on the transmutation of species. [75]

Proper scientific explanations employ *verae causae* in principle accessible to all observers, which supernatural action manifestly is not, and so on. [76]

Thus at the fountainhead of the dominant scientific explanation of origins we find uncertainty about the "scientific" status of design or creation theories. Such theories are testable --yet they are not testable. They engage the facts by real predictions -- yet they say nothing about the facts beyond what the facts themselves already told us.

The cynical reading of this uncertainty (a posture endemic throughout evolutionary theory today) looks no further than the pragmatism of "any stick will do to beat a dog." That is, where the religiously-motivated opponents of evolution are concerned, we need not make too great a virtue of consistency. Get (and keep) theology out of science, by any means necessary, if it comes to that. Niceties about testability or empirical content are quite beside the point. There is too much at stake.

The cynical reading, while it may be true, is almost too bleak to bear. It implies that science is not a truth-seeking enterprise, but something closely approximating advertising or propaganda, where success in the competition (however that be defined) is everything. I don't believe this --

actually, I can't bear to believe it -- and hope the reader doesn't either. Suppose then that we lay aside the cynical reading as too dispiriting.

The charitable reading of the uncertainty about the scientific status of design suggests that it reflects philosophical confusion. Somewhere in the deeper logic of our current conception of scientific explanation, we have made, or overlooked, a very serious blunder. Among the elements of what Gerald Holton calls "the modern world picture" -- that is, the received scientific world picture -- there exist profoundly inconsistent epistemological commitments. [77] Put more simply, if what we want is the truth about how the world and its creatures came to be, then we may not be able to tell that story in fully naturalistic terms. Because the truth -- to modern eyes ungainly, even ugly -- may be otherwise.

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NOTES

1. Douglas Futuyma, *Evolutionary Biology* 2nd edition (Sunderland, Mass.: Sinauer Associates, 1986), 15. By "evolution" I mean what Doolittle calls the "widely accepted" theory that "all Life on Earth today is descended from a common ancestral organism that existed sometime between 1.5 and 3.0 billion years ago" -- this evolution occurring by means of the natural selection of undirected and randomly arising variation (Russell R. Doolittle, "New Perspectives on Evolution Provided by Protein Sequences," in *New Perspectives on Evolution*, eds. L. Warren and H. Koprowski [New York: Alan Liss, 1991], p. 165).
2. Salvador Luria, Stephen Jay Gould, and Sam Singer, *A View of Life* (Menlo Park, California: Benjamin/Cummings, 1981), p. 581.
3. George Williams, *Natural Selection: Domains, Levels, and Challenges* (Oxford: Oxford University Press, 1992), pp. 72-73.
4. Bruce Alberts, "The Function of Hereditary Materials," *American Zoologist* 26 (1986): 786-787.
5. See, e.g., Francisco J. Ayala and James Valentine, *Evolving: The Theory and Processes of Organic Evolution* (Menlo Park, California: Benjamin/Cummings, 1979), 5; Niles Eldredge and Joel Cracraft, *Phylogenetic Patterns and the Evolutionary Process* (New York: Columbia University Press, 1980), 3; Stanley Beck, "Natural Science and Creationist Theology," *BioScience* 32 (1982), 739-740; D. Futuyma, *Science on Trial*, 169-170; Anne Riddiford and David Penny, "The scientific status of modern evolutionary theory," in *Evolutionary Theory: Paths into the Future*, ed. J.W. Pollard (New York: John Wiley, 1984), 18; S.J. Gould, "Darwinism Defined: The Difference between Fact and Theory," *Discover*, January 1987, 70; Antoni Hoffman, *Arguments on Evolution* (Oxford: Oxford University Press, 1989), 11-12.
6. From Phillip Johnson, Stephen Meyer, Alvin Plantinga, Jitse van der Meer, and J.P. Moreland, among others.
7. Ernst Haeckel, *The History of Creation* (New York: D. Appleton, 1876), 291.

8. See, e.g., Francois Jacob, "Evolution as Tinkering," in *The Possible and the Actual* (New York: Pantheon, 1982); Elliott Sober, *The Nature of Selection* (Cambridge, Mass.: MIT Press, 1984), 175-76; Douglas Futuyma, "Evolution as Fact and Theory," *Bios* 56 (1985), 6; Richard Dawkins, *The Blind Watchmaker* (New York: W.W. Norton, 1986), 91-94; Richard Burian, "Why the panda provides no comfort to the creationist," *Philosophica* 37 (1986), 11-25.
9. Stephen J. Gould, *Ever Since Darwin* (New York: W.W. Norton, 1977), 91.
10. Stephen J. Gould, *The Panda's Thumb* (New York: W.W. Norton, 1980), pp. 20-21.
11. Stephen J. Gould, *Hen's Teeth and Horse's Toes* (New York: W.W. Norton, 1983), 160, 164.
12. *Ibid.*, p. 258.
13. Stephen J. Gould, "Evolution and the Triumph of Homology, or Why History Matters," *American Scientist* 74 (1986), 63.
14. Gould, "Triumph of Homology," 64.
15. See, for instance, Reinhard Junker and Siegfried Scherer, *Entstehung und Geschichte der Lebewesen* (Giessen: Weyel Lehrmittelverlag, 1988); Chris Darnbrough, "Genes -- created but evolving," in *Concepts in Creationism*, eds. E.H. Andrews, W. Gitt, and W.J. Ouweneel (Herts, England: Evangelical Press, 1986), 241-266; and Hendrik Murriss, "The concept of the species and its formation," 175-207, in the same volume.
16. Douglas Futuyma, *Science on Trial* (New York: Pantheon, 1983), 198.
17. Wayne Frair and Percival Davis, *A Case for Creation* (Chicago: Moody Press, 1983), 29.
18. Bruce Naylor, "Vestigial Organs are Evidence of Evolution," *Evolutionary Theory* 6 (1982), 94.
19. Murriss, "Concept of the species," 200-201.
20. Junker and Scherer, *Geschichte der Lebewesen*, 126.
21. Reinhard Junker, *Rudimentare Organe und Atavismen: Konstruktionsfehler des Lebens?* (Berlin: Studium Integrale, Zeitjournal Verlag, 1989).
22. Darnbrough, "Genes -- created but evolving," 252-262.
23. See Mill's Three Essays on Religion, in particular, the essay on "Theism," Part I, especially the Introduction and chapter 6, and Part II, "Attributes." Bertrand Russell discusses a similar conception of the creator: "He need not be omnipotent or omniscient; He may be only vastly wiser and more powerful than we are. The evils in the world may be due to his limited power. Some theologians have made use of these possibilities in forming their conception of God" (*History of Western Philosophy*, New York: Simon & Schuster, 1945; 589).
24. Gould, "Panda's thumb," 28.
25. Thanks for Frank Arduini for this phrase.
26. Hume's *Dialogues Concerning Natural Religion*, especially Part V, is the classical expression of the difficulties that follow from considering the full range of logically possible supreme beings (creators).
27. John Hick, "Evil, The Problem of," in *The Encyclopedia of Philosophy*, ed. Paul Edwards (1967), 137.

28. See Augustine, *On Order*.
29. G.W. Leibniz, *Theodicy* (La Salle, Illinois: Open Court, [1710], 1985), 206-207.
30. Gould, *Panda's Thumb*, 28, emphasis added.
31. *Ibid.*, 28-29.
32. The literature on optimality theory and its difficulties is very extensive. The "epistemological difficulties" I have in mind are best explained by Richard Lewontin, in his essay "The Shape of Optimality," in *The Latest on the Best*, ed. John Dupre (Cambridge, Mass.: MIT Press, 1987), pp. 151-59.
33. Gould, "Triumph of Homology," 66.
34. John Maynard Smith, "Optimization Theory in Evolution," *Annual Review of Ecology and Systematics* 9 (1978), 32. Under the heading, "What is possible?," R. McNeill Alexander takes up the same question. "The next problem, after deciding what is likely to be optimized, is to decide what structures or strategies are possible, and what constraints apply. If no such limitations were recognized it would have to be concluded that optimum structure would make bones unbreakable and without mass, and an optimum life-history would involve immortality and infinite fecundity" (*Optima for Animals* [London: Edward Arnold, 1982], 97).
35. Lewontin, "The Shape of Optimality," 156.
36. Gould, *Panda's Thumb*, 24.
37. *Ibid.*, 21.
38. George Schaller, H. Jinchu, P. Wenshi, and Z. Jing, *The Giant Pandas of Wolong* (Chicago: University of Chicago Press, 1986), 4; emphasis added.
39. *Ibid.*, 58; emphasis added.
40. See Nicholas Rescher, *Leibniz: An Introduction to his Philosophy* (Oxford: Basil Blackwell, 1979), chapter VI, for an explication of such compossibility arguments within Leibniz's philosophy.
41. Richard C. Lewontin, "Adaptation," in *Conceptual Issues in Evolutionary Biology*, ed. Elliott Sober (Cambridge, Mass.: MIT Press, 1984), 234-251.
42. Lewontin, "Shape of Optimality," 158-59.
43. Gabriel Nelson kindly pointed this out to me.
44. Francisco J. Ayala, "Evolution, The Theory of," *Encyclopedia Britannica*, 15th ed. (Chicago: Encyclopedia Britannica, 1988), 987, emphasis added.
45. Darwin, *Origin of Species*, 435.
46. A.J. Cain, "The perfection of animals," in *Viewpoints in Biology*, Volume 3, eds. J.D. Carthy and C.L. Duddington (London: Butterworths, 1964), 44.
47. Ronald Brady, "On the Independence of Systematics," *Cladistics* 1: 113-126; p. 114.
48. E.S. Russell, *Form and Function* (Chicago: University of Chicago Press, 1982 [1916]), p. 214.
49. Olivier Rieppel, *Fundamentals of Comparative Biology* (Basel: Birkhauser Verlag, 1988), pp. 49-51.

50. Darwin, *Origin of Species*, p. 458.
51. *Ibid.*, p. 434.
52. *Ibid.*, p. 435.
53. Cain, "Perfection of animals," p. 44.
54. Richard Owen, *On the Nature of Limbs* (London: John Van Voorst, 1849), p. 70.
55. *Ibid.*, p. 10.
56. *Ibid.*
57. *Ibid.*, p. 40; emphasis added.
58. Ayala, "Evolution, The Theory of," p. 987.
59. Neal Gillespie, *Charles Darwin and the Problem of Creation* (Chicago: University of Chicago Press, 1979), p. 71.
60. Charles Darwin, *On the Various Contrivances by Which Orchids Are Fertilized by Insects* (Chicago: University of Chicago Press, [1877] 1984), pp. 245-46.
61. Darwin performed numerous experiments (the description of which constitutes much of the book) to understand the functional aspects of orchid fertilization. In the last chapter, he draws this moral from the experiments: "No one who has not studied Orchids would have suspected that these and very many other small details of structure were of the highest importance to each species; and that consequently, if the species were exposed to new conditions of life, and the structure of the several parts varied ever so little, the smallest details of structure might readily be acquired through natural selection. These cases afford a good lesson of caution with respect to the importance of apparently trifling particulars of structure in other organic beings" (*Various Contrivances*, p. 287).
62. See Michael Ghiselin, *The Triumph of the Darwinian Method*, 2nd edition, Chicago: University of Chicago Press, 1984.
63. Soren Lovtrup, *Darwinism, The Refutation of a Myth* (London: Croom Helm, 1987), p. 132.
64. See, e.g., Gillespie, *Charles Darwin and the Problem of Creation*, J.H. Brooke, "The Relations Between Darwin's Science and his Religion," in *Darwinism and Divinity*, ed. J. Durant (London: Basil Blackwell, 1985), pp. 40-75, and Cornell, "God's Magnificent Law."
65. Cornell, "God's Magnificent Law," pp. 384-385.
66. Dov Ospovat, "God and Natural Selection: The Darwinian Idea of Design," *Journal of the History of Biology* 13 (1980), pp. 189-190.
67. Cornell, "God's Magnificent Law," p. 396.
68. *Ibid.*, p. 397.
69. Brooke, "Relation between Darwin's Science and his Religion," p. 46.
70. Mayr, "Darwin, intellectual revolutionary," p. 25.
71. The literature on this question is vast; for a representative selection of opinion, see Leszek Kolakowski, *Religion* (Oxford: Oxford University Press, 1982); Langdon Gilkey, *Creationism on Trial* (Minneapolis: Winston Press, 1985); Keith Yandell, "Protestant Theology

and Natural Science in the Twentieth Century," in *God and Nature*, eds. D.C. Lindberg and R.L. Numbers (Berkeley: University of California Press, 1986), pp. 448-471; and Stephen J. Gould, "Darwinism Defined," p. 70.

72. Ernst Mayr, Introduction to the facsimile reprint of the *Origin of Species* (Cambridge, Mass.: Harvard University Press, 1964), p. xii.

73. Charles Darwin, *On the Origin of Species* (Cambridge, Massachusetts: Harvard University Press, 1964 [facsimile reprint of 1st edition]), 186, 435.

74. David L. Hull, "Darwin and the nature of science," in *Evolution from Molecules to Men* (Cambridge: Cambridge University Press, 1983), D.S. Bendall, ed., 71.

75. *Ibid.*, 64-65.

76. Jonathan Hodge has led among Darwin scholars in interpreting this aspect of Darwin's scientific outlook: "The epistemological rationale for [Lyell's] presumption, of the persistence of all . . . causes of change into the present and future, is the ideal of explanation by real or existing causes, *verae causae*. Like his friend (and the undergraduate Darwin's scientific hero) the physicist John Herschel (1792-1871), Lyell followed earlier writers, most notably the Scottish philosopher Thomas Reid (1710-1796), who had drawn this moral from the superior evidential credentials of the Newtonian gravitational force over the Cartesian ethereal vortices: any causes invoked in an explanatory theory should, ideally, be known to exist through direct observation independently of the facts they are supposed to explain. . . . Such, then, was the context, at once systematic and epistemological wherein Darwin, from 1834 on, was theorizing about species extinctions and origins" ("The development of Darwin's general biological theorizing," in *Evolution from Molecules to Man*, ed. D.S. Bendall [Cambridge: Cambridge University Press, 1983], 45-46).

77. The "items characterizing a modern world picture," Holton argues, include a "high place for 'objectivity'," a "proof-oriented" outlook, "demanding verification or test of falsification," "skepticism with respect to authority," and an "avowedly secular, anti-metaphysical" standpoint (Gerald Holton, *Science and Anti-Science* [Cambridge, Mass.: Harvard University Press, 1993], 173-74). The philosophical confusion reading of the uncertainty about the scientific status of design suggests that if design is true, the "avowedly secular" element of the modern world picture is mistaken -- and whether design is true cannot be settled by appealing to the "avowedly secular" element of the modern world picture, without begging the question.

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