Charles Darwin's Theory of Evolution: An Analysis

MICHAEL RUSE
Department of Philosophy
University of Guelph
Guelph, Ontario

I want in this paper to give an analysis of Charles Darwin's theory of evolution, or, as he would have called it, his theory of descent with modification. This analysis will not be directly concerned with the way Darwin arrived at his theory – much has been said about this elsewhere[1] – rather, what I shall be looking at basically is the *nature* of the finished theory as Darwin gave it to us in the first edition of the *Origin of Species.*[2] I shall argue that although many writers have had important insights about Darwin's theory, no one has as yet given an entirely satisfactory picture of the theory.

At the center of Darwin's theory, obviously, is his mechanism of evolutionary change – natural selection. I shall open my discussion by looking at the way Darwin introduced this mechanism into the *Origin.* Natural selection, however, is not all that there is to the *Origin.* Darwin began his attack on the problem of organic origins by considering the changes man has wrought in domestic organisms – pigeons and the like. The nature and relevance of this reference to manmade change will form the second part of my discussion. Next, I shall look at Darwin's argumentation in the *Origin* after he introduced natural selection. Finally, I shall draw together the various strands of my discussion in order to give a synoptic view of Darwin's theory.

NATURAL SELECTION

Darwin's mechanism of evolutionary change, natural selection, rests essentially on the claim that some organisms are, by virtue of the

1. See, for example, F. N. Egerton "Studies of Animal Populations from Lamarck to Darwin," *J. Hist. Biol., 1,* (1968), 225–259; Egerton, "Humboldt, Darwin, and Population," *J. Hist. Biol., 3* (1970), 325–360; R. M. Young, "Malthus and the Evolutionists; The Common Context of Biological and Social Theory," *Past and Present, 43* (1969), 109–145; P. Vorzimmer, "Darwin, Malthus, and the Theory of Natural Selection," *J. Hist. Ideas, 30* (1969), 527–542; and C. Limoges, *La sélection naturelle* (Paris: Presses Universitaires de France, 1970).

2. London: Murray, 1859.

Journal of the History of Biology, vol. 8, no. 2 (Fall 1975), pp. 219–241.

special "useful" characteristics they have, better at the task of surviving and reproducing than other organisms, and that thus there is a "differential reproduction" between organisms, having the consequence that some (i.e. "useful") characteristics will get passed on in higher proportions than other characteristics. As is well known, Darwin did not just drop natural selection into his discussion without argument. First he argued to something he called the "struggle for existence." Then, having done this, he went on to use his conclusion about the struggle to argue for natural selection.

By the "struggle for existence" Darwin admitted he meant "struggle" taken both literally and metaphorically; he also admitted that by "existence" he meant not so much survival as success in leaving offspring. Thus Darwin claimed that "two canine animals in a time of dearth, may be truly said to struggle with each other which shall get food and live."[3] But he extended the term to cover a desert plant "struggling" against drought, or a mistletoe plant "struggling" with other plants "in order to tempt birds to devour and thus disseminate its seeds rather than those of other plants."[4] In short, the struggle seems to cover almost anything that an organism might do to ensure its survival and reproduction.

Darwin argued for the existence of the struggle as follows:

> A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase. Every being, which during its natural lifetime produces several eggs or seeds, must suffer destruction . . . otherwise, on the principle of geometrical increase, its numbers would quickly become so inordinately great that no country could support the product. Hence, as more individuals are produced than can possibly survive, there must in every case be a struggle for existence . . . Although some species may be now increasing, more or less rapidly, in numbers, all cannot do so, for the world would not hold them.[5]

Then Darwin linked the struggle with natural selection.

> How will the struggle for existence . . . act in regard to variation? . . . Can it . . . be thought improbable . . . that . . . variations useful in

3. Darwin, *Origin*, p. 62.
4. Ibid., p. 63.
5. Ibid., pp. 63–64.

> some way to each being in the great and complex battle of life, should sometimes occur in the course of thousands of generations? If such do occur, can we doubt (remembering that many more individuals are born than can possibly survive) that individuals having any advantage, however slight, over others, would have the best chance of surviving and of procreating their kind? On the other hand, we may feel sure that any variation in the least degree injurious would be rigidly destroyed. This preservation of favourable variations and the rejection of injurious variations, I call Natural Selection.[6]

How do we evaluate these passages? The obvious model to compare them against is that proposed by what is today probably the most prevalent philosophical school, so-called logical empiricism.[7] The logical empiricist argues that scientific theories are "hypothetico-deductive" systems, by which he means two things: first, that scientific theories are axiomatic systems, that is, that one starts with a number of propositions unproven within one's system (axioms), and then, from these, one infers deductively all one's other propositions (theorems); secondly, that what distinguishes scientific axiomatic systems from other such systems is that the former, unlike the latter, contain propositions which are "laws" or "lawlike." What precisely makes something a law is a matter of some debate; but all generally agree that a law is a true, universal proposition which is in some sense necessary – this necessity, however, is not logical, but in some way empirical.

Several people have suggested, without qualification, that Darwin's arguments to natural selection fit the logical empiricist model;[8] others have denied this.[9] What I would suggest is that the model seems more appropriate than not, but that there is certainly no exact fit. Take first

6. Ibid., pp. 80–81.

7. I discuss logical empiricism in detail in my book *The Philosophy of Biology* (London: Hutchinson, 1973).

8. M. Bunge, *Scientific Research* (New York: Springer-Verlag, 1967); A. C. Crombie, "Darwin's Scientific Method," *Actes IXe Cong. Int. Hist. Sci.* (Barcelona), *I* (1960), 324–362; H. Lehman, "On the Form of Explanation in Evolutionary Theory," *Theoria, 32* (1966), 14–24; M. Ghiselin, *The Triumph of the Darwinian Method* (Berkeley: University of California Press, 1969); A. G. N. Flew, "The Structure of Darwinism," *New Biology, 28* (1959), 18–34.

9. T. A. Goudge, *The Ascent of Life* (Toronto: University of Toronto Press, 1900); A. R. Manser, "The Concept of Evolution," *Philosophy, 40* (1965),18–34; A. D. Barker, "An Approach to the Theory of Natural Selection," *Philosophy, 44* (1969), 271–290.

the question of structure. It is undeniable that, as given, Darwin's arguments are not rigorously deductively valid. If they were, then given the truth of his premises (axioms), his conclusions (theorems) would *have* to follow. But this is not so for Darwin's arguments. Suppose, for example, there were regular catastrophes wiping out huge numbers of organisms, regardless of what the organisms tried to do to save themselves. One could then have a high tendency of organisms to increase, and one could also have a world of limited room, but the need for any kind of struggle, metaphorical or otherwise, might never arise.

Nevertheless, it is clear that Darwin's arguments can, fairly easily, be *reconstructed* into a rigorously deductive form, by the addition of premises which Darwin probably took as being so obviously true as not to need explicit stating.[10] Thus, for example, one might reconstruct the argument to the struggle for existence as follows.

Premise i: Organic beings tend to increase at a high (geometrical) rate.

Premise ii: If organic beings tend to increase at a high rate, then either there must be a struggle for existence or the numbers of organisms go up without limit.

Premise iii: If the numbers of organisms go up without limit, then the world must have unlimited room.

Premise iv: The world does not have unlimited room.

Conclusion: There is a struggle for existence.

Then, in a similar manner, one might reconstruct the argument to natural selection.

Premise i: There is a struggle for existence.

Premise ii: Some organisms have useful heritable variations.

Premise iii: Some organisms have injurious heritable variations.

Premise iv: If there is a struggle for existence and if some organisms have useful heritable variations and if some organisms have injurious heritable variations, then organisms with useful heritable variations have a better chance of surviving and reproducing than organisms with injurious heritable variations.

10. Some reasons for the particular reconstructions I offer can be found in my papers "Natural Selection in *The Origin of Species*," *Stud. Hist. and Phil. Sci., 1* (1971), 311–351; and "The Nature of Scientific Models: Formal *v* Material Analogy," *Phil. Soc. Sci, 3* (1973), 63–80.

Conclusion: Organisms with useful heritable variations have a better chance of surviving and reproducing than organisms with injurious heritable variations.

These arguments of Darwin, what I think one might appropriately refer to as the "core" arguments of the *Origin*, are now in a rigorously deductive form. Moreover, it can be seen clearly that not much reconstruction of Darwin's actual arguments was needed to achieve this form; indeed, the second argument needed little more than the (clearly presupposed) third premise, and the first argument needed only strengthening in such a way as to exclude such things as (obviously nonexistent) alternatives to the struggle for existence. It seems therefore that from the viewpoint of *structure* it is not inappropriate to consider Darwin's core arguments as approximating closely to the hypothetico-deductive ideal.

But, even granting that Darwin's arguments are deductive in some sense, do they consist of laws? Here we find a greater divergence from the hypothetico-deductive ideal. A law, as I have pointed out, is a true, universal statement that, although not logically necessary, seems in some way "to have to hold." Thus, given a fixed mass of gas (at normal temperatures and pressures) Boyle's law has to hold of it, whereas although universally true, there seems no necessity that Canadian prime ministers be always male. Various criteria have been proposed for the recognition of laws. One of the most useful and popular is that laws are found to hold not merely in a wide variety of different circumstances, but in situations and circumstances not thought of when the law was first proposed. When a law holds under these conditions, one starts to feel that the truth of the law is not something "built in" by its proposer, but something which really reflects reality. Thus Mendel's laws seem convincingly necessary because they have been found to hold for so many organisms, most unthought of by Mendel working with his pea plants. If we use a criterion like this, some of Darwin's statements in his arguments do seem to qualify as laws. Thus, for instance, his claim that organic beings tend to increase at a high rate holds universally true for organisms of all different kinds, for organisms known by Darwin and organisms not known by Darwin, so that one must surely agree that if anything is to be counted as a law, it is to be counted.[11] One feels somehow that it *has* to hold. Equally, however, some of

11. See J. M. Smith, *The Theory of Evolution* (Middlesex: Penguin, 1958), p. 33.

Darwin's statements as they stand to not qualify as laws. Take, for example, the claim that the world does not have unlimited room. This, while true, is no law, if only because it is not a universal statement. It is making a claim about the properties, or lack of properties, of some particular thing.

Now, it is certainly true that, having started upon the path of reconstruction, one could continue until one has Darwin's arguments in such a state that they contain nothing but apparent laws. Thus, for example, one might change Darwin's premise "the world does not have unlimited room" to something along the lines of "given any group of organisms there is a limit to the extent that they can expand in number, without either running out of room in some absolute sense or without infringing on the territory of other organisms." With changes like this, and corresponding changes in other premises, one can hope to finish with something approaching laws throughout. But there is a price to be paid, of course. The more one reconstructs, the further one goes from Darwin's actual arguments, and consequently the less justification one has for claiming that one's end product is truly "Darwinian."

In consequence, perhaps the fairest thing to say about Darwin's core argument with respect to the hypothetico-deductive ideal is as follows. Darwin's arguments, taken literally, are neither deductive nor solely composed of laws. However, they are close to being deductive, and might fairly be taken as being such. Also, the arguments do contain some laws. But not all of the statements of the arguments are in any sense lawlike. One can certainly convert the arguments into forms which contain nothing but laws – but at a price. One has to deviate in some considerable amount from what Darwin actually offered us. Probably, given what I shall show later about Darwin's own intensions, such a reconstruction is permissible – permissible, that is, if one is to stay within the bounds of what is genuinely Darwinian – but in making it one ought to speak of Darwin's arguments as being hypothetic-deductive "sketches" or "proposals," rather than implying that they fully exemplify the hypothetico-deductive ideal.

DOMESTIC ORGANISMS

I turn now to Darwin's discussion before the introduction of the struggle for existence and natural selection. In the first chapter of the *Origin*, "Variation under Domestication," Darwin started by considering the great differences existing between domesticated organisms, particularly between different varieties of the same kind of organism

– sheep, dogs, plants, pigeons, and so on. But, he argued, despite popular opinion to the contrary, all varieties (of the same kind of organism) come originally from the same parent stock (or from a limited number of original forms). He considered in some detail the example of pigeons to support this claim, and then he speculated on the causes of all of these differences. He wrote: "We cannot suppose that all the breeds were suddenly produced as perfect and as useful as we now see them; indeed, in several cases, we know that this has not been their history. The key is man's power of accumulative selection: nature gives successive variations; man adds them up in certain directions useful to him. In this sense he may be said to make for himself useful breeds."[12]

For the rest of the chapter Darwin elaborated on man's selection, and then, in the second, rather brief chapter, "Variation under Nature," he argued that much variation can be found between organisms occurring in the wild. In particular, he argued that there are many slight variations, which he called "individual differences." Then, after that, he was ready to present the arguments I considered in the first section of this paper.

Now, one thing that Darwin was doing in these early chapters was telling us, in part, how he himself got led to his theory – he grasped the idea of artificial selection and through this was led to the idea of natural selection.[13] And, presumably, the reason Darwin told us about his theory's genesis was so that we, by retreading his path, might be brought more easily to the major and controversial parts of his theory. But the important question is whether this was the only function of Darwin's discussion in his first two chapters. If it was, then it might with some justification be argued that the discussion in a significant sense does not belong to Darwin's theory proper (which begins with the argument to the struggle for existence). Rather, it might be argued that the reference to artificial selection is merely a heuristic aid to enable the newcomer to natural selection more easily to grasp its essential nature and effects. On the other hand, if Darwin's reference to artificial selection had more than a heuristic function, then the question arises of precisely what this extra function was. Moreover, if we assume this function was one which definitely incorporates artificial selection *within* Darwin's theory, the question also arises as to what strain this puts on a hypothetico-deductive characterization of Darwin's overall theory.

12. Darwin, *Origin*, p. 30.

13. See M. Ruse, "Charles Darwin and Artificial Selection," *J. Hist. Ideas*, **36** (1975), 339–350.

What I shall argue is that the first two chapters of the *Origin* were important for Darwin just as much for the *support* they gave to his theory as for their illustration of his thought processes, enabling the new reader more easily to grasp the contentious points of the theory.[14] Furthermore, I shall argue that this support, although part of Darwin's theory, was not linked deductively with the rest of the theory, and that hence, in an least one place in the *Origin*, Darwin's method of inference was analogical or, more generally, inductive. In other words, I shall suggest that grave doubt must be thrown on the supposed overall hypothetico-deductive nature of Darwin's theory (even if we ignore the point I made previously about the nonlawlike nature of some Darwin's premises).

That Darwin's discussions of artificial selection and of variation in the wild do have a justificatory role in his thought emerges clearly from his arguments toward natural selection. Consider for a moment Darwin's claims about the existence of favorable and injurious variations, which, as we have seen, occur as premises in Darwin's arguments to natural selection. What evidence did Darwin give for the claims? He wrote: "Let it be borne in mind how infinitely complex and close-fitting are the mutual relations of all organic beings to each other and to their physical conditions of life. Can it, then, be thought improbable, seeing that variations useful to man have undoubtedly occured, that other variations useful in some way to each being in the great and complex battle of life, should sometimes occur in the course of thousands of generation?"[15] Obviously, at this point Darwin was supporting his premises by an analogical argument. But what is this argument? It goes something like this.

Premise i: Heritable variations which are useful to man occur in domestic organisms (argued for in Chapter 1).

Premise ii: Heritable variations occur in wild organisms (argued for in Chapter 2).

Conclusion: Some (wild) organisms have heritable variations useful to them in the struggle for existence (concluded in the chapter on natural selection).

Presumably, although Darwin did not give it explicitly, a parallel

14. See also M. Ruse, "The Value of Analogical Models in Science," *Dialogue, 12* (1973), 243–253.

15. Darwin, *Origin*, p. 80.

argument was intended to yield the existence of injurious variations. Then, as we have seen, these conclusions were used as premises in a deductive argument. Thus what we have are analogical arguments in some sense being presupposed by (some of) the deductive arguments in the core of Darwin's theory. And these analogical arguments are based on information given in the first two chapters of the *Origin*.

But where does this leave the supposed hypothetico-deductive nature of Darwin's theory? With respect to the question of laws, the situation does not look too bad. Darwin's statements are not strictly lawlike, but one can convert them to the required form fairly easily. Thus, for example, the second premise can be converted to the lawlike form "given any group of wild organisms, they will contain heritable variation." However, when we consider the kind of inferences Darwin relied on, the picture for the hypothetico-deductive theorist does not look so rosy. There is nothing deductive at all about the argument given above. Apparently, therefore, we have to recognize that at least part of Darwin's theory used analogical and not deductive argument.

There are two obvious moves the hypothetico-deductive theorist might make before allowing this. First he might try to deny that the analogical argument is actually part of Darwin's theory; secondly, he might try to convert the analogical argument into a deductive one. Let us take these counter-moves in turn.

If one were to deny that the analogical argument is actually part of the theory, then I suppose that one's claim would be that in some sense what Darwin was offering in the first two chapters of the *Origin* was evidence for the premises of his (hypothetico-deductive) theory; but one's claim would also be that this evidence was itself not an actual part of the theory. The trouble with this kind of move is that it lays open the way to the removal of a good deal (if not all) of the deductive structure of Darwin's theory, as well as the analogical parts. Consider for a moment the argument that Darwin gave for natural selection. Key premises are that there is a struggle for existence and that there are useful variations. The former premise Darwin justified deductively, the latter premise Darwin justified inductively. If one is not to make the hypothetico-deductive thesis true by fiat (and I think its supporters usually want to claim that in some sense they are describing the practice of science as well as prescribing its ideal course), I can see no overwhelming reason why one should be allowed to exclude from Darwin's theory the argument for the second premise, if one intends to keep within the theory the argument for the first premise. But if, for the sake of deductive purity, one jettisons both arguments, why not

throw out the argument to natural selection as well? And so, for the sake of a philosophical thesis, Darwin's theory starts to reduce down to a bare statement of the principle of natural selection. If we are to avoid this, and I think we should, then I think we must learn to live with Darwin's arguments for different kinds of variation.

The other face-saving move for the hypothetico-deductive theorist is to try to convert Darwin's analogical argument into a deductive argument. There are two difficulties with this move. In the first place, I am not sure just what kind of general premise would suffice to make Darwin's argument deductive – at least I am not sure of any premise which has any vague hope of being both true and factual. One seems to need a premise like "Whenever one has a group of organisms, some of them will have some variations which are in some sense useful to someone, possibly themselves or possibly someone else." This woolly statement is a much weaker reed than anything on which Darwin in fact rested his case. And this brings me to the second difficulty. Other than for the sake of saving the hypothetico-deductive thesis, why should one convert Darwin's argument into a deductive one? There is no evidence that Darwin *really* thought deductively – indeed we all often argue analogically without in any sense presupposing general premises which would make our arguments deductive. I may buy a second pair of shoes from a store because my first pair wore very well without at all supposing that every pair of shoes from the store wears well (or that every pair of a more limited kind wears well). Darwin did not give us a deductive argument, there is no evidence that he intended to give us a deductive argument (although he thought his conclusion was well taken, as we often do in the case of analogical arguments) – indeed, he tells us explicitly in his correspondence that he is using an analogical argument[16] – therefore I see no reason to make his argument deductive. At this point, the hypothetico-deductive model does not fit.

DARWIN'S ARGUMENTS BASED ON NATURAL SELECTION

We come now to that part of the *Origin*, much the largest part, which comes after the demonstration of the existence of natural selection. Here Darwin showed how the continued (evolutionary) effects of natural selection could be used to solve problems in geology, paleon-

16. "In fact the belief in Natural Selection must at present be grounded entirely on general considerations [including] the analogy of change under domestication by man's selection." Letter to G. Bentham, in F. Darwin, ed., *Life and Letters of Charles Darwin* (London: Murray, 1887), III, 25.

tology, geographical distribution, morphology, embryology, and so on. Following the previous pattern of discussion, let us once again address ourselves to the question of whether or not we find that Darwin's work exemplifies the hypothetico-deductive model. What I strongly suspect is that in fact in no place in the *Origin* do we ever find an actual exemplification of a genuinely, rigorously deductive inference from a lawlike hypothesis (or from a number of hypotheses some of which are lawlike). Take for example a passage late in the fourth chapter where Darwin gave one or two imaginary illustrations to show how natural selection leads to evolutionary change. Here, if anywhere, particularly since Darwin chose imaginary rather than real examples and so could set up the situation in a manner most favorable to his theory, we should expect to find deductive rigor. However, we do not.

In the passage to which I am referring, Darwin was trying to explain how and why a group of wolves might evolve in the direction of increased ability to run quickly, and he wrote as follows:

> Let us take the case of a wolf, which preys on various animals, securing some by craft, some by strength, and some by fleetness; and let us suppose that the fleetest prey, a deer for instance, had from any change in the country increased in numbers, or that other prey had decreased in numbers, during that season of the year when the wolf is hardest pressed for food. I can under such circumstances see no reason to doubt that the swiftest and slimmest wolves would have the best chance of surviving, and so be preserved or selected, – provided always that they retained strength to master their prey at this or at some other period of the year, when they might be compelled to prey on other animals.[17]

Clearly there is here no really deductive justification of the claim that later generations of wolves will run faster than earlier generations. Apart from anything else, no appeal has been made to the laws of heredity; but, looking at Darwin's illustration with our knowledge of modern genetics, we know that it it possible that Darwin's premises are true and his conclusion false. For example, the fastest wolves might be heterozygotes for a pair of alleles whose homozygotes are fairly slow. Despite selection for heterozygotes, the population might have reached a balanced situation where random interbreeding would continue to produce in each generation the same proportion of homozygotes. In

17. Darwin, *Origin*, p. 90.

other words, the relative proportion of fast and slow wolves would remain constant.

I am not saying that this would ever actually be the case for wolves;[18] but the point is that were Darwin offering us deductive arguments or, at least, were he offering us valid deductive arguments, then if his premises were true, his conclusion would have to be true. My counter-example shows this not to be the case. Of course, it might be claimed that my choosing this example is a little unfair, since at the point at which Darwin gave this argument he could hardly appeal to the laws of heredity: the illustration about the evolution of wolves occurs in the fourth chapter; but it is not until the fifth chapter that Darwin dealt in any detail with the laws of heredity, specifically, with the laws governing the introduction of new variation. Perhaps only after this could we expect Darwin to work with deductive rigor.

However, this defense of Darwin really does not solve very much. In the first place, it does not alter the fact that the passage I am considering does not contain a deductively rigorous argument. In the second place, even a hasty perusal of Darwin's fifth chapter ("Laws of Variation") shows that it is hardly likely to bring us to a precise exemplification of the hypothetico-deductive model. Essentially, the chapter contains information about a collection of things which Darwin thought might lead to the introduction of new heritable variation. In this collection there are, for example, the effects of changes in the conditions of life affecting the reproductive systems of organisms, the effects of the conditions of life directly impinging on organisms, and the effects of use and disuse. Rather than leading one to think that Darwin's arguments are close to being put on a firm deductive basis, this discussion, if anything, directs one's thoughts in the opposite direction. Admittedly, in his later work, *The Variation of Animals and Plants Under Domestication,*[19] Darwin did try to work out some coherent theory of heredity ("pangenesis"), but he never put this theory into the later editions of the *Origin*; and in any case, even if one draws on the theory

18. Such "balanced" situations do actually occur, of course, even if not in the particular case of wolf-fleetness. The maintenance of the sickle-cell gene in African populations living in malarial districts is the classic example. I discuss this case in some detail in *The Philosophy of Biology* and in "Some Thoughts on Programmes for Improving Mankind" in *Proceedings of the Fifth Conference on Value Inquiry* (New York: Gordon and Breech, 1900).

19. London: Murray, 1868.

of heredity, none of Darwin's arguments are automatically converted into deductive arguments.[20]

A definitive demonstration of the fact that Darwin (in the *Origin*) never adhered to a rigorous hypothetico-deductive form would involve a case-by-case examination of all of his arguments, something obviously beyond the scope of this paper. Unfortunately, those who argue for the hypothetico-deductive nature of Darwin's theory tend not to give much by way of example in support of their claims (examples other, of course, than the central arguments I have already discussed). Indeed, the only person I have found who gives an example from the part of the *Origin* under discussion and who claims that it is deductive is E. E. Harris.[21] He gives the following example drawn from the final chapter of the *Origin*:

> The existence of closely allied or representative species in any two areas, implies, on the theory of descent with modification, that the same parent-forms formerly inhabited both areas: and we almost invariably find that wherever many closely allied species inhabit two areas, some identical species are still common to both. Wherever many closely allied yet distinct species occur, doubtful forms and varieties belonging to the same groups likewise occur. It is a rule of high generality that the inhabitants of each area are related to the inhabitants of the nearest source whence immigrants might have been derived. We see this in the striking relation of nearly all the plants and animals of the Galapagos archipelago, of Juan Fernandoz, and of other American islands, to the plants and animals of the neighbouring American mainland; and of those of the Cape de Verde archipelago, and of the other African islands to the African mainland.[22]

Here, argues Harris, we find an exemplification of the hypothetico-deductive method, as we always do whenever Darwin writes "we should expect to find, and we do find . . ."

Clearly, however, whatever we may feel about the value of what Darwin has written in this passage, we do not have deductive arguments. Letting *A, B,* and *C,* stand for species, Darwin's claim was roughly as shown in Fig. 1. However, consider Fig. 2, where *D, E,* and *F*

20. Pangenesis is no more presented in a rigorously hypothetico-deductive form than are the arguments of the *Origin.*

21. *Hypothesis and Perception* (London: Allen and Unwin, 1970).

22. Darwin, *Origin,* p. 478; quoted from later edition by Harris, *Hypothesis,* p. 182.

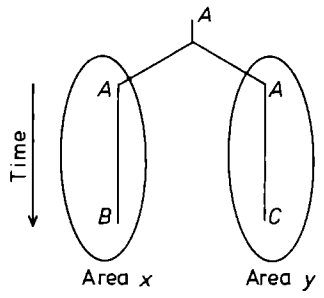

Fig. 1.

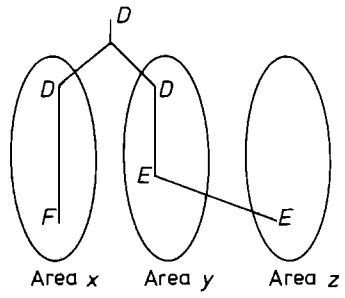

Fig. 2.

represent species. This possibility is not inconsistent with Darwin's theory. But here, although we have closely allied species (F and E), it is not the case that common ancestors existed in areas X and Z (although possibly X and Z are closer than X and Y). Hence, Darwin's argument is not deductive.

Possibly we could turn Darwin's words around and argue that his important claim was that the similarity between, say, the birds on the Galápagos Archipelago and the South American mainland can be explained by his theory of natural selection (together with certain assumptions about common ancestry). But even if Darwin would argue this (and, of course, he would),[23] we still have no deductive arguments. The lack of an adequate theory of heredity rules out this possibility.

I suggest therefore, in the absence of evidence to the contrary, that the later parts of the *Origin* do not contain rigorously deductive arguments. But if this is the case, how then is it best to interpret the arguments that Darwin gives? Given the discussion as it has gone so far, two rival interpretations spring to mind. The first interpretation is that the latter parts of the *Origin*, like the core parts, give us hypothetico-deductive sketches (although these parts would under consideration be a great deal more sketchy even than the core parts). The second interpretation is that we have nondeductive arguments – analogies and other kinds of inductions – which in no sense ought to be viewed in a deductive light. One's natural inclination might be to choose the second of these two interpretations. Not only is it the weaker of the two interpretations, and thus ipso facto easier to argue for, but also in some respects it might seem to be the fairer of the two. To argue for a

23. See, for example, the two chapters on geographical distribution in the *Origin*.

hypothetico-deductive-sketch viewpoint necessarily implies that there is something incomplete about Darwin's theory. In itself, perhaps there is nothing pernicious about this; but it does leave the sneaking suspicion that there, as so often, we are having a biological theory evaluated (to its detriment) by criteria appropriate only to physical theories (many of which do actually satisfy the hypothetico-deductive ideal). But, in Michael Scriven's words, has not the time now come when "in place of the social scientists' favourite Myth of the Second Coming (of Newton), we should recognize the Reality of the Already-Arrived (Darwin)"?[24]

Nevertheless, attractive though this second option may be, I still think there is at least one good reason for not ignoring the hypothetico-deductive-sketch interpretation of the parts of Darwin's theory under discussion. This is that if we are to take seriously Darwin's own words about what he was trying to do in the *Origin*, then there is a strong prima facie case that what Darwin intended to offer us was (the analogy from domestic selection apart) a hypothetico-deductive system. The hypothetico-deductive ideal obviously derives primarily from the physical sciences, Newtonian astronomy in particular. Hypothetico-deductive theorists, seeing that astronomy exemplifies such an ideal, argue that it is the appropriate ideal for all of science. But we know that Darwin agreed that Newtonian astronomy is the appropriate ideal for science – indeed, he himself wanted to provide the biological equivalent. Thus, before discovering his theory he wrote: "Astronomers might formerly have said that God ordered each planet to move in its particular destiny. In same manner God orders each animal created with certain form in certain country. But how much more simple and sublime power – let attraction act according to certain law, such are inevitable consequences – let animals be created, then by the fixed laws of generation, such will be their successors."[25] Moreover, in the *Origin* itself Darwin spoke of having shown that, from laws, "the production of the higher animals, directly follows."[26] And this is certainly to claim to have exemplified the hypothetico-deductive ideal.

Now, obviously, there is no logical connection between what a man intends and what he achieves, and indeed I have shown that Darwin did not exactly succeed in achieving the hypothetico-deductive ideal. Apart

24. "Explanation and Prediction in Evolutionary Theory," *Science, 130* (1959), 477–482.

25. Gavin de Beer, ed., "Darwin's Notebooks on Transmutation of Species," *Bull. Brit. Mus. Nat. Hist., Historical Series, 2*, no. 2 (1960), 53 (Species notebook "B," pp. 101–102).

26. Darwin, *Origin*, p. 490.

from his reliance on nonlaws in his core arguments, few if any of his arguments were rigorously deductive. Nevertheless, Darwin did rely on some laws, and in his core arguments he got close to the deductive ideal. Hence, if our analysis is not to diverge from what Darwin himself would have wanted to claim, it seems proper to think of the arguments following his demonstration of natural selection as being in a rather loose sense sketches of hypothetico-deductive arguments.[27]

There is, however, one large qualification that I would want to make to this conclusion. This resolves around the use Darwin made of the analogy from artificial selection. We have seen how Darwin argued analogically from the existence of variations favorable or otherwise to man's wishes to the existence of variations favorable or injurious to their possessors in the struggle for existence. At that point, Darwin's theory did not fit the hypothetico-deductive pattern. Moreover, not only is it difficult to see how it could be made to fit the pattern, but since Darwin himself specifically referred to the link between the artificial world and the natural world as an analogy, there is little reason to think, on the basis of Darwin's own intentions, that at that point Darwin's theory should fit the hypothetico-deductive pattern. However, after the chapters in the *Origin* in which Darwin proved the existence of natural selection, we continue to get repeated mentions of artificial selection, and again I think we get violations of the hypothetico-deductive pattern. Let me explain how this comes about.

When discussing topics in the *Origin* after the introduction of natural selection (and after his discussion of the laws of variation), Darwin referred constantly to the conclusions he drew about the struggle for existence and natural selection. But it was clearly not the case that when working in (what I might call) the "lower-level disciplines" – morphology, embryology, taxonomy, and so on – Darwin relied exclusively on conclusions drawn from his core arguments. The lower-level disciplines, of course, contained assumptions derived from sources other than the core, some of these being peculiar to one particular discipline, and some being shared by more than one. Darwin gave many illustrations of such lower-level (i.e., non-core) assumptions. For example, in his discussions of geographical distribution, while explaining the nature of the inhabitants of archipelagos, he relied on

27. Backing this conclusion is the fact that contemporary philosophies of science, to which Darwin was most sensitive, were strongly advocating the hypothetico-deductive ideal. See M. Ruse, "The Darwin Industry– A critical Evaluation," *Hist. Sci. 12* (1974), 43–58; Ruse," Darwin's Debt to Philosophy", *Stud. Hist. Phil. Sci., 6* (1975),159–181.

(non-core) assumptions about methods and possibilities of transport from one part of the earth to another. And in the relevant places Darwin discussed in detail his reasons for assuming that such methods of transport are not merely possible, but to be expected. For example, he argued that seeds can be transported for many miles over the sea if they are embedded in driftwood.[28]

However, when we come to consider many of the (non-core) assumptions in the subsidiary areas, the lower-level disciplines, what we find is that Darwin argued for their truth *analogically* from claims he made about artificial selection. Thus, for example, in his discussion of embryology, one of the things Darwin was trying to explain was why embryos are so frequently radically different from the adult forms. His reason, in part, was that the selective pressures experienced by embryos and adults are often very different. But this fact, of course, did not alone explain the difference in the structures. Darwin also had to appeal in some way to the laws of heredity, arguing that there was no reason to suppose that new characteristics always appear in embryos in these characteristics' adult form, and that in fact some characteristics appear only in the adults and unless there is a selective pressure forcing the characteristics to appear in earlier stages of development there is no reason why they should ever do so. Hence he was able to conclude that because selection varies through an organism's development, so also the organism's structure varies.

But when we inquire into the reasons Darwin offered for these (crucial) assumptions about variation, with their consequent effects on structure, we see that what Darwin did was to argue analogically from domestic organisms. He invited us to "look at a few analogous cases in domestic varieties,"[29] and he argued (in part) as follows:

> Fanciers select their horses, dogs, and pigeons, for breeding, when they are nearly grown up: they are indifferent whether the desired qualities and structures have been acquired earlier or later in life, if the full-grown animal possesses them. And the cases just given, more especially that of pigeons, seem to show that the characteristic differences which give value to each breed, and which have been accumulated by man's selection, have not generally first appeared at an early period of life, and have been inherited by the offspring at a corresponding not early period.[30]

28. Darwin, *Origin*, chap. 11, "Geographical Distribution."
29. Ibid., p. 444.
30. Ibid., p. 446.

Then, having made his point in the domestic world, Darwin argued that an analogous situation holds in a state of nature.

Now, clearly, we have here no deductive link between the way in which variation appears in domestic organisms and the way in which it appears in wild organisms, and given the fact that at this point in the *Origin* Darwin did indeed refer to the link as being an analogy, it might with reason be argued that no deductive argument was intended and that a deductive interpretation is inappropriate. And this could well also be true of the other (frequent) passages where Darwin invoked the domestic-organism analogy. Thus one might argue that although a large part of Darwin's theory is hypothetico-deductive (in a sketched form), this structure is, as it were, intermeshed with a great many analogical threads running from domestic organisms to wild organisms.

Of course, as before, the hard-line hypothetico-deductive theorist will have a reply to an argument like this. He will probably argue that even the frequent references to domestic organisms need not point to a failure of his model. He will suggest that what we find is that Darwin used examples drawn from domestic organisms to justify general claims about all organisms, which he then applied deductively to wild organisms. But it will also be argued that no hypothetico-deductive theorist would want to deny that in justifying his general claims the scientist (when not deriving the claims from more general claims) cannot work deductively – the scientist must work inductively from specific examples. The hypothetico-deductive thesis, its supporter will claim, is about the theory proper and begins only when one has one's general statements.

The trouble with this argument, I think, is precisely what was wrong with the argument when it was used against the inclusion in Darwin's theory of the analogical inference from one kind of variation (variations in domestic organisms and useful to man) to another kind of variation (variations in wild organisms and useful to the possessors). Apart from the question of the truth of the assumption that one can in fact find satisfactory general premises covering both domestic and wild organisms, one does seem rather to be defending the hypothetico-deductive thesis, not on its own merits, but by legislation. What fits the hypothetico-deductive model is part of the theory, what does not fit the model is not part of the theory. Thus, when Darwin justified his claims deductively, this was part of his theory; but when he justified his claims analogically, this was not part of the theory. However, unless one decides a priori that the only real parts of scientific theories are deductions from laws (in which case it is not that surprising that one

"discovers" that all theories are hypothetico-deductive), I am not really sure that one should be able to pick and choose the various kinds of justifications that Darwin offered for his different claims. His explanation of the facts of embryology involved two kinds of claims, each justified in a different way: The claims about selection he justified (albeit sketchily) deductively. The claims about when characteristics appear during development he justified analogically from domestic organisms. Given Darwin's claim at the beginning of his final chapter, namely, that "this columne is one long argument,"[31] I cannot see that one can justifiably exclude one set of Darwin's arguments and still maintain that there is nothing in Darwin which deviates from the hypothetico-deductive form.

Of course, supposing that the case I made earlier about Darwin's support of a hypothetico-deductive ideal is a reasonably strong one, I do realize that, in arguing in the way in which I have just done, I am suggesting or seem to be suggesting that some of Darwin's own claims or intentions about the nature of scientific theories do not seem to be exemplified in his theory of the *Origin*. For this reason, it might be suggested that all of the non-hypothetico-deductive arguments of the *Origin* (including the analogy from artificial selection in the core part of his theory) must either be construed as deductive sketches or regarded as not part of the theory itself. I do confess to a lack of comfort in having to oppose this view; but, apart from anything else, Darwin himself was never that consistent on this point. Despite his avowal of the hypothetico-deductive ideal, he seems always to have regarded the reference to the domestic world as part of his theory, and he spoke of it always as having an *analogical* link with the natural world.

Possibly, the best course of action is not to worry too much about a problem like this. In a sense, what is at stake here is little more than a verbal squabble, revolving around the question of exactly which of a scientist's arguments one is prepared to allow are part of a scientist's theory proper and which are part of the discussion around a theory, and the question of how much reconstruction is allowable while still retaining a scientist's original theory. There is no dispute here (by those who are prepared to accept that some kind of hypothetico-deductive imputation is appropriate in the case of Darwin's theory) that although essential parts of Darwin's argument are hypothetico-deductive (in sketched form), other parts are not. The problem is, does one exclude these latter parts from the theory, does one include them in the theory

31. Ibid., p. 459.

as they are (recognizing that they are in no sense deductive), or does one insist on reconstructing them in a deductive form before including them in the theory?

I feel inclined to include the unreconstructed, nondeductive parts, specifically the analogy from domestic organisms, in Darwin's theory proper. This analogy, because of the incredibly large number of references to it, seems to be such an integral part of Darwin's thinking that any portrayal of the "essential" nature of his theory which omits all or nearly all mention of the analogy can only have purchased support for a philosophical thesis by removing (or excluding or downgrading) some of the best parts of Darwin's evolutionary thought. Moreover, for reasons given, the analogy seems not to lend itself to reconstruction into a deductive form. Consequently, as I understand Darwin's "theory," it includes more than just deductions from general statements. Among other things it includes nondeductive arguments in order to get statements required to make deductions (or, more accurately, deductive sketches), as for example when in his discussion of the facts of embryology Darwin argued analogically to required premises about the point in development when new variations appear in (wild) organisms.

Enough has been said about the details of Darwin's method of argument. The time has now come to see if we can pull together the various strands of discussion in order to achieve a synoptic view of Darwin's theory of evolution.

THE OVERALL STRUCTURE OF DARWIN'S THEORY

The basic question to be answered is whether or not it is possible to present Darwin's theory as a unified whole or whether we should rather consider the theory in some other way. I think that we can properly see the theory as one unified whole, integrating many areas of investigation. At least, I think we can see Darwin's theory of *natural selection* as a unified whole, although it should not be forgotten that Darwin did not think that natural selection was the sole cause of evolutionary change. Since this point often is forgotten or ignored in analyses of Darwin's theory, perhaps it deserves more than passing mention here, before I attempt to present a full view of the theory.

For a start, we must recognize that Darwin thought that there was a second kind of selection – *sexual selection.* He wrote about this that it "depends, not on a struggle for existence, but on a struggle between the males for possession of the females; the result is not death to the

unsuccessful competitor, but few or no offspring."[32] Also, Darwin made it clear, he believed that there was sexual selection due to female choice: "I can see no good reason to doubt that female birds, by selecting, during thousands of generations, the most melodious or beautiful males, according to their standard of beauty, might produce a marked effect."[33]

Then, quite apart from selection, Darwin thought that there were other causes of evolutionary change, for example, *use and disuse.* One instance where Darwin appealed to use and disuse was in his discussion of instinct. There he wrote: "As modifications of corporeal structure arise from, and are increased by, use or habit, and are diminished or lost by disuse, so I do not doubt it has been with instincts."[34] He did add, however, that he thought the effects of use and disuse to be far less than the effects of natural selection working on (what we today would call) random variations.

How one would best integrate Darwin's views on use and disuse into his theory of natural selection I am not quite sure; indeed, Darwin wrote in such a loose way about them that I doubt that there is any proper way. Sometimes use and disuse seem to be working on variations in conjunction with natural selection, and sometimes independently of it. Darwin certainly had no definite ideas about the exact relative importance of use and disuse to selection, nor did he seem able to say when exactly selection would be the main agent of change and when use and disuse would take over.

Perhaps one can be a little more successful in putting sexual selection into Darwin's overall theory, for it, like natural selection, seems ultimately to be a product of too many beings after too little space and food. In the passage given above from the *Origin*, sexual selection seems not to be a product of the struggle for existence, but the product of some kind of parallel "struggle for mates." Hence, what we might do is replace the earlier argument I gave with the conclusion that there is a struggle for existence with a slightly modified argument with the conclusion that there is both a struggle for existence and a struggle for mates (and obvious with slightly modified premises to keep it valid). Then we could take the second part of this conclusion (i.e., there is a struggle for mates), and add another argument (akin to the argument to natural selection) to get sexual selection, thus:

32. Ibid., p. 88.
33. Ibid., p. 89.
34. Ibid., p. 209.

Premise i:	There is a struggle for mates.
Premise ii:	Some organisms have useful variations (i.e., they have sexually useful variations).
Premise iii:	Some organisms have sexually injurious variations.
Premise iv:	If there is a struggle for mates and if some organisms have sexually useful variations and if some organisms have sexually injurious variations, then organisms with sexually useful variations have a better chance of reproducing than organisms with sexually injurious variations.
Conclusion:	(Sexual Selection.) Organisms with sexually useful variations have a better chance of reproducing than organisms with sexually injurious variations.

In this way, Darwin's claims about sexual selection could be integrated into his theory of natural selection, although points of detail like the relative importance of the two kinds of selection would be left open.

Now, with Darwin's views on natural and sexual selection put together, we can see a fairly clear integrated pattern in his overall theory of evolution through selection. There is a core part to the theory, ending with the affirmation of the existence of natural selection and sexual selection. This is arrived at partly deductively and partly analogically (in the text, the deductive arguments are not rigorous, but rigorous forms can be readily reconstructed). Then, this core is used to throw light (in some fashion) on all the many other different areas of biological inquiry – geographical distribution, behavior, taxonomy, morphology, embryology, and so on. A simplified diagram of the overall situation is shown in Fig. 3. It should be noted that Fig. 3 is simplified, at least to the extent that I have not tried to include in it Darwin's rather hazy ideas about use and disuse and so on.[35] Nor have I tried to show what other evidence might be fed into the lower-level subjects (such as evidence about methods and possibilities of transport) – sometimes the supplying of evidence might require an analogical or deductive jump from one lower-level discipline to another, as for example when one might use findings from the science of geographical distribution to interpret aspects of the fossil record in paleontology. I have, however, taken the liberty of showing analogical links between

35. P. Vorzimmer, *Charles Darwin: The Years of Controversy* (Philadelphia: Temple University Press, 1970), has the most recent, detailed discussion of Darwin's various views on the sources of heritable change.

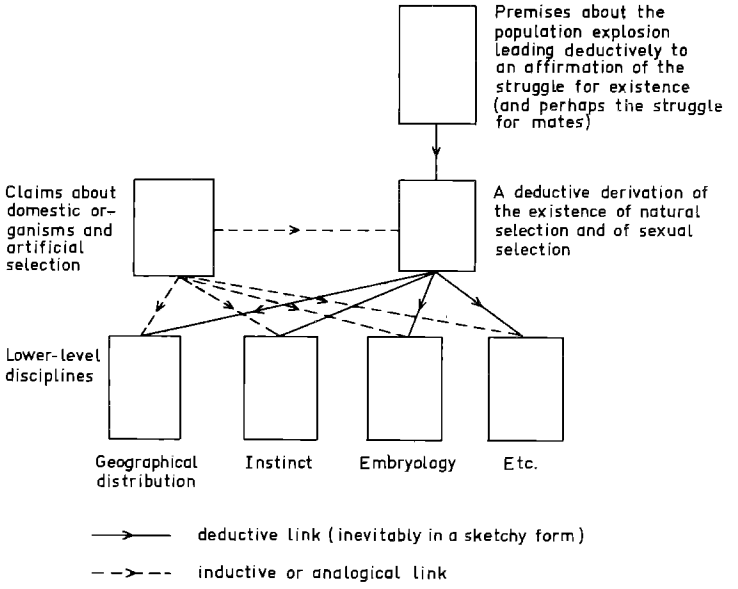

Fig. 3.

Darwin's claims about domestic organisms and all of his arguments at the lower level. I would not want to claim that one must always have a direct analogical link between a lower-level discipline and claims about domestic organisms, although in the *Origin*, there almost inevitably is one.

And now, finally, I think that the overall structure of Darwin's theory has been laid bare.[36] Darwin's theory has a far more complex structure than most commentators have suggested. Indeed, perhaps the best metaphor to apply to the theory – particularly if we remember that superimposed upon my diagram must be the links caused by Darwin's views about variation (other than those analogical links which come from domestic organisms) and the links between the lower-level disciplines – is that of a *very fine network*, where many different threads mesh together to make the whole. Certainly, those who assert flatly that the theory is hypothetico-deductive overstate the case; but those who deny the relevance of any kind of axiomatic approach at all seem no nearer to the truth. The true answer lies in the middle position argued to in this paper.

36. The reader might be interested in comparing this diagrammatic representation of Darwin's theory with a similar kind of representation that I give of the modern theory of evolution in *The Philosophy of Biology*, p. 49.