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Reconsidering the Structure of Darwin's 'Long Argument'

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Abstract

Darwin describes the *Origin of Species* as 'one long argument'. The exact structure of this argument has been the subject of controversy among philosophers of biology. I will propose a novel analysis that sheds new light on Darwin's argument. The central claim will be that the evidence that supports the theory of common descent can only satisfactorily support it after the theory of natural selection has been regarded as an in principle possibility. This account helps us understand some enigmatic features of the structure of the *Origin* and has consequences for evidentialism and Bayesianism as applied to Darwin's argument.

1. Introduction

According to Darwin's theory of evolution, populations of organisms change gradually over time and often split into new species, forming a common branching tree of life. The main cause of evolutionary change is natural selection, which produces adaptations. Natural selection is thus what explains evolutionary change and the common descent of organisms. That evolutionary change and common descent have occurred is in turn based on a wealth of evidence, such as fossils and biogeographical observations, as well as morphological and embryological homologies.

Based on this brief description of the basic structure of Darwin's theory, one would expect that the best way to present the theory would be to start with the evidence supporting the hypotheses that evolution has occurred and that species share a common ancestor, and only after that to introduce natural selection as the main cause of evolutionary change. Considering the current state of research in evolutionary biology, this would seem appropriate for a further reason: while no biologist today would dispute the claim that species evolve and share a common ancestor, the thesis that natural selection has been the only (or the most) significant cause of

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evolutionary change has given rise to substantial debate.[1] However, this is not the order of presentation followed by Darwin in the *Origin of Species*. There, natural selection is introduced first, followed by the hypothesis of common descent and the evidence supporting it. The purpose of this paper is to understand why Darwin follows this order of presentation.

In what follows I will examine the general epistemological structure of the argument in the *Origin*, which Darwin famously describes as 'one long argument'. While the exact structure of this argument has been the subject of controversy among historians and philosophers of biology, in this paper I will focus on two analyses of Darwin's argumentation in the *Origin*. The first account, given by Jonathan Hodge (1977) and in a series of publications since then (see Hodge 1989, 2013; White et al. 2021), is the now widespread view among historians and philosophers of biology that Darwin adopts the method of Herschel. The second account (which can be viewed as complementary to that of Hodge) has been proposed by Elliott Sober (2011). The reason I focus especially on these two views is that they will serve to motivate my alternative analysis, but also because they include important insights that any analysis has to take into account.[2] I will begin with a brief discussion of the main features of these two views, that will serve as background and motivation for the main claims of the paper. Next, I will offer a new analysis of the general epistemological structure of Darwin's argumentation in the *Origin*, present textual and other evidence in favour of it, and draw some more general consequences for evidentialism and Bayesianism as applied to Darwin's argument.

2. The structure of the *Origin*

The structure of the *Origin* can be divided into three main parts.[3] The first part (chapters 1–5) presents the theory of natural selection as a cause of evolutionary change. In the first chapter artificial selection is discussed, leading to the conclusion that modification within a species is in principle possible; chapters 2–4 show that an analogous process can exist in nature. Chapter 2 concerns the variation that exists within natural populations and chapter 5 presents various laws of variation. Chapter 3 concerns the struggle for existence – here the 'doctrine of Malthus' is applied to nature. In chapter 4 Darwin draws on the discussions of the previous chapters and shows that: (i) the existence of variations within populations and the doctrine of Malthus lead to the selection of favourable variations; (ii) if these favourable variations can be inherited (what he calls the 'strong principle of inheritance'), they remain in the population and are further modified. Ultimately, if this process is repeated over many generations, it leads to the creation of complex adaptations of organisms to the environment, the extinction of many species, as well as the continuous divergence of organismic characters (what Darwin calls the 'principle of divergence').

[1] As evidenced, for example, in recent discussions concerning the 'Extended Synthesis' (see Laland et al. 2015).

[2] I will not, for reasons of space, discuss Kenneth Waters' (2003) important discussion of the structure of Darwin's argument; however, I will indicate in the last section a main difference between his analysis and mine.

[3] I follow the division of the *Origin* as presented in White et al. (2021).

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In the second part of the *Origin* (chapters 6–8) the main difficulties for the theory of evolution by natural selection are discussed, for example how the transition from simple to complex structures takes place, as well as the difficulties posed by instincts and hybrids.

Finally, in the third part (chapters 9–13) the evidence in favour of the theory of common descent is presented, which includes the geological succession of organisms and their geographical distribution, as well as morphological and embryological affinities. It is argued that these observations only make sense on the theory of common descent, while on the alternative of 'special creation', they are left unexplained.

Based on the above, two important observations can be made regarding the structure of the *Origin*: first, the hypothesis of common descent (and thus the hypothesis that evolution has occurred), as well as the kinds of evidence that support it, are presented in the last part of the book, while the theory of natural selection, which is the cause of evolution, is introduced at the beginning; second, in the last part of the book Darwin seems to contrast the theory of special creation to the theory of common descent, and not to the theory of evolution by natural selection. A satisfactory analysis of the *Origin*, i.e. an explanation of why Darwin structures his presentation of the theory in this way, has to explain why the structure of his 'long argument' has these seemingly odd features.

3. The Herschelian strategy

Jonathan Hodge (1977, 1989, 2013; see also White et al. 2021) has offered a well-known analysis of Darwin's strategy in the *Origin* that has been widely accepted. According to Hodge, the Darwinian 'long argument' for the origin of species by natural selection has to be understood in terms of the establishment of natural selection as a Herschelian 'true cause' (*vera causa*). According to Herschel, to establish a *vera causa* one must begin with cases where the action of the cause has been observed; such cases according to Darwin are examples of artificial selection, which he presents in the first chapter of the book. From these cases Darwin proceeds to cases in which the action of selection must be inferred; this is done in chapters 2–5, where the conditions that occur in nature that permit the action of natural selection – variation and struggle for existence – are examined. Next, according to the Herschelian strategy, it must be shown that the true cause is capable of producing the phenomena. This is done in part in chapters 1–5, and also in chapters 6–8 of the book where the difficulties of the theory are discussed. Finally, it must be shown that the true cause was indeed responsible for producing the phenomena. This is done in the remaining chapters 9–13.

Hodge's analysis explains why the theory of natural selection is presented at the beginning of the *Origin*. However, there remains a puzzle, as such an analysis does not explain the fact that in the last part of the book the theory of natural selection does not play a central role. This point, i.e. the fact that Darwin seems to neglect the theory of natural selection in the last part of the book and instead focuses on the contrast between the theory of special creation and common descent, has led scholars to the position that Darwin's 'long argument' is not actually a single argument, but has two parts: it consists, first, of a Herschelian argument for establishing natural selection as

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a true cause, which is presented in the first part of the book, and second, of an argument based on Whewell's consilience of inductions and which mainly concerns the hypothesis of common descent and is developed in the second part of the book – see Waters (2003) for development of this view.

4. Sober's analysis

Elliott Sober's (2011) analysis sheds further light on the structure of Darwin's argument. Sober argues that the Herschelian strategy alone cannot explain the structure of the *Origin* and that Darwin's book is in a way written backwards. He starts with the observation that Darwin's theory consists of two distinct parts: the hypothesis of common descent and the hypothesis of natural selection. These two hypotheses, according to Sober, are not only logically independent of each other, but also have an asymmetric relationship to the evidence that supports them. In particular, the evidence that supports the hypothesis of common descent does not depend on natural selection having actually acted. In contrast, specific claims about the action of natural selection rest on claims about the common descent of organisms. Thus, the hypothesis of common descent has, according to Sober, evidential priority.

To support his claim Sober relies on what he calls 'Darwin's Principle' (Sober 2011, section 1.3). According to this principle, adaptive similarities between organisms provide almost no evidence for common ancestry, while similarities involving traits that are adaptively useless or even harmful to the organisms that possess them provide strong evidence for common ancestry.

Sober analyses 'Darwin's principle' by means of the Law of Likelihood. According to this law, for hypotheses H1 and H2 and observation O, observation O supports hypothesis H1 over hypothesis H2 when $P(O \mid H1) > P(O \mid H2)$ (where $P(A \mid B)$ is the probability of A given that B has occurred). The expression $P(O \mid H)$ is called the likelihood of hypothesis H, where the likelihood of H differs from the probability of H, $P(H \mid O)$. The previous inequality therefore shows which of the two hypotheses, H1 and H2, is favoured by observation O. We can have a quantitative form of the law of likelihood by taking the ratio of the likelihoods:

$$\frac{P(O|H_1)}{P(O|H_2)}$$

This ratio tells us the extent to which observation O favours H1 over H2. The law of likelihood expresses the intuitive idea that given an observation O and two hypotheses that are both compatible with observation O, the observation favours that hypothesis which makes the observation less unexpected.

The law of likelihood is related to Darwin's principle as follows. The observation in this case is that two organisms A and B are similar in some respect (they both have trait T). The two hypotheses are, first, that the two organisms share common ancestry (CA), and second, that they have separate ancestry (SC for 'special creation', i.e. for the hypothesis that species have been created separately, which is the hypothesis that Darwin compares to the hypothesis of common descent in the *Origin*). Darwin's principle concerns two cases: first, the case where the similarity concerns an adaptive trait; second, the case where the similarity concerns a non-adaptive trait:

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$$\frac{P(A \ \& \ B \text{ have T} \mid CA)}{P(A \ \& \ B \text{ have T} \mid SC)} \approx 1, \text{if T is adaptive}$$

$$\frac{P(A \ \& \ B \text{ have T} \mid CA)}{P(A \ \& \ B \text{ have T} \mid SC)} \gg 1, \text{if T is not adaptive}$$

For example, consider the hydrodynamic shape of dolphins and sharks. In this example, which involves an adaptive feature in these two organisms, the likelihood ratio is approximately 1. But now, consider the example of gill slits in human embryos and fish embryos. In this case, the similarity concerns a non-adaptive trait (since gill slits in human embryos are considered to be non-adaptive). The likelihood ratio in this example is much greater than 1.

Sober claims that Darwin's general argument in favour of common descent rests on 'Darwin's principle' and can be analysed in terms of the above likelihood ratios. The crucial point is that Darwin's principle does not presuppose the truth of the hypothesis that natural selection is the main cause of evolution. Specifically, what the principle presupposes is that (1) if natural selection favoured the evolution of trait T in the lineages leading to species A and B, then the fact that A and B both have trait T provides little or no evidence as to whether CA or SC is true. At the same time, Darwin's principle does not presuppose that (2) natural selection has favoured the evolution of one or more traits in the lineages leading to species A and B. Therefore, the inference from the observations to the hypothesis of common descent does not rest on the claim that natural selection has occurred. Sober also argues that the opposite is true: specific hypotheses about the action of natural selection in specific lineages rest on the assumption of common descent.[4]

Sober arrives at the following evidential structure of Darwin's argumentation: first, Darwin infers from various kinds of evidence the common descent of organisms; it follows that populations can change to such an extent that speciation can occur; finally, Darwin shows (through the Malthusian argument, the analogy with artificial selection, and many examples of adaptive traits) that natural selection explains adaptive traits. And yet, the structure of the *Origin* follows the reverse order; this is why Sober claims that in terms of the evidential priority of the two main components of the theory (common descent and natural selection) the book is written backwards. So, the order actually followed in the *Origin* is explained by Sober by the fact that Darwin decided to structure his argument on the basis of the causal priority between common descent and natural selection. The causal priority of the two components is the inverse of the evidential priority, since natural selection causes evolutionary change (leading to the branching structure of the tree of life and to common descent) and not the other way around.

5. A novel analysis of the structure of the *Origin*

I will now argue that an analysis of the structure of the *Origin* is possible which, while retaining the main features of Hodge's and Sober's analyses, does not have the somewhat paradoxical consequence that the book has been written (evidentially)

[4] The reason for this is, as Sober puts it, that 'common ancestry provides a framework within which hypotheses about natural selection can be tested. Thanks to common ancestry, facts about the history of natural selection become knowable' (2011, 39).

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backwards. At the same time, this analysis will help us understand why in the third part of the *Origin* natural selection does not seem to play a prominent role. The main idea of the account I propose is that the evidence supporting the theory of common descent, presented in the third part of the book, can satisfactorily support the theory only when the theory of natural selection has been considered as an in principle possibility. Thus, first, Sober's central idea of evidential priority is retained, in the sense that the inference of common descent does not presuppose the truth of the theory of natural selection, and second, it becomes clear that the theory of natural selection is presented first not simply because it has causal priority, but because only then can the argument in favour of common descent become fully plausible.

That this is the main reason why Darwin structures his book in this way can also be seen from the following passage from his Introduction:

> In considering the Origin of Species, it is quite conceivable that a naturalist, reflecting on the mutual affinities of organic beings, on their embryological relations, their geographical distribution, geological succession, and other such facts, might come to the conclusion that each species had not been independently created, but had descended, like varieties, from other species. Nevertheless, such a conclusion, *even if well founded, would be unsatisfactory*, until it could be shown how the innumerable species inhabiting this world have been modified, so as to acquire that perfection of structure and coadaptation which most justly excites our admiration. ... [other theories leave] the case of the coadaptations of organic beings to each other and to their physical conditions of life, untouched and unexplained. ... It is, therefore, of the highest importance to gain a clear insight into the means of modification and coadaptation. (Darwin 1859, 3–4, emphasis added).

Darwin's argument in the above passage can be reconstructed, on the basis of the previous discussion, as follows. We have at our disposal various kinds of evidence (morphological, embryological, biogeographical, geological) that support the hypothesis of common descent. These observations are much less unexpected under the hypothesis of common descent, compared to the hypothesis of special creation. At the same time, however, there exists a great epistemological obstacle to accepting that all kinds of organisms form a single evolutionary tree; this epistemological obstacle consists in the fact that the complex adaptations and co-adaptations of organisms cannot be explained, as it is evident that no existing theory is satisfactory in this regard (Darwin cites as examples of unsatisfactory causal hypotheses for the explanation of adaptations the action of external conditions, the habits of organisms, and the will of organisms). Thus, for the inference from the evidence to the hypothesis of common descent to be satisfactory, one has to explain how evolutionary change is possible in such a way that complex adaptations and co-adaptations can be produced.

It is crucial here that what is missing to make the inference satisfactory is not a detailed explanation of 'how the innumerable species inhabiting this world have been modified, so as to acquire that perfection of structure and coadaptation'. Such a thing would have been in any case impossible. Rather, what is needed is to understand how adaptations are *in principle* possible. And this is Darwin's main goal, in my opinion, in the first part of the *Origin*. More specifically, the central claim of the analysis I propose

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is the following: in order for Darwin to successfully support the hypothesis of common descent, he has first to propose a plausible theory about how organismal adaptations are produced. The theory of natural selection is such a plausible theory: when this theory is accepted as an in principle possibility, we can have a very high degree of confidence in the hypothesis of common descent; the degree of confidence in the theory of natural selection is an independent matter (and can in any case be lower than the degree of confidence one has in the hypothesis of common descent).

The final epistemic state to which we are led by means of Darwin's argument can also be seen from the following quotation, which is again from the Introduction of the *Origin* (the difference between 'I can entertain no doubt/fully convinced' and 'convinced' is very important here):

> *I can entertain no doubt*, after the most deliberate study and dispassionate judgment of which I am capable, that the view which most naturalists entertain, and which I formerly entertained – namely, that each species has been independently created – is erroneous. I am *fully convinced* that species are not immutable; but that those belonging to what are called the same genera are lineal descendants of some other and generally extinct species, in the same manner as the acknowledged varieties of any one species are the descendants of that species. Furthermore, I am *convinced* that Natural Selection has been the main but not exclusive means of modification. (6, emphasis added)

This difference between the degrees of confidence in the two main components of Darwin's theory (common descent and natural selection) also explains, I think, further claims made by Darwin, which show that the theory of natural selection is of secondary importance to him, such as the following: 'personally, of course, I care much about Natural Selection, but that seems to me *utterly unimportant*, compared to the question of *Creation or Modification*' (from a letter to Asa Grey on May 11, 1863, emphasis added). It moreover explains the seemingly odd feature of the book we noted in section 2, i.e. why in the second part of the *Origin* the theory of natural selection does not have a prominent role. Finally, it makes epistemological sense of a very widespread attitude during the last quarter of the nineteenth century among biologists; while most of them were 'fully convinced' of the hypothesis of common descent, many were not convinced of the truth of the theory of natural selection (see Bowler 1992).

Let us close by briefly discussing the general epistemological significance of this analysis of the evidential structure of Darwin's argument. For someone who adopts evidentialism, changes in what we are justified in believing are always associated with changes in the total evidence. But let us assume that the evidence in favour of evolution was known before the publication of the *Origin* (which is of course to simplify matters considerably, since Darwin presents new evidence in the *Origin*, e.g. biogeographical evidence). Then, if the degree of justification of the theory of common descent before and after the publication of the *Origin* is different, this must be because what seems to be the same evidence supports the hypothesis more strongly after the publication of the book. This change in the degree of justification of the theory of common descent is due to the introduction of the hypothesis of natural selection.

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This argument illustrates a phenomenon that is analogous to something already known in epistemology: often the simple introduction of an alternative hypothesis H2 can undermine the degree to which the evidence supports hypothesis H1. The epistemic situation in the *Origin* is a bit different: the introduction of the hypothesis of natural selection *increases* the degree to which the evidence supports the hypothesis of common ancestry. Therefore, strictly speaking, the evidence in the two instances (i.e. before and after the publication of the *Origin*, on the assumption that the morphological, embryological, and other kinds of evidence in favour of evolution remained the same) is different, since, given evidentialism, the justification of what one is justified in believing supervenes on the total evidence. This means that, for the evidentialist, the total evidence for the reader of the *Origin* must be taken to include the hypothesis of natural selection as an in principle possibility.

Furthermore, the current account of the evidential structure of Darwin's 'long argument' has consequences for a simple Bayesian analysis. Let us assume hypothesis CA (common ancestry) and hypothesis SC (special creation) that have certain prior probabilities, and let us also assume the morphological, embryological, and other evidence presented by Darwin. According to my analysis, the posterior probability of CA is greater for someone who knows the theory of natural selection than for someone who does not know the theory. But I argued that the theory of natural selection is in the first place posited as an in principle possibility, and its truth (just as Sober claims) is not presupposed for the hypothesis of common descent. Thus, the difference in the degree of belief in CA in the two instances (i.e. before and after the publication of the *Origin*, again on the assumption that the morphological, embryological, and other kinds of evidence in favour of evolution remained the same) is not due to some newly discovered evidence, and thus at least a simple Bayesian account of this case is incomplete.[5]

6. Conclusions

To summarise: Darwin's main purpose in the *Origin* is to support the hypothesis that all present-day organisms have descended through modification and branching evolution from common ancestors. Branching evolution produces, and explains, geological, biogeographical, morphological, and embryological observations, but also a major 'given in natural history', the Linnaean taxonomic hierarchy itself (see Winsor 2009). Full support of this hypothesis presupposes the existence of a plausible and general theory of organismal adaptations. This theory is natural selection, which in turn is the cause of branching evolution. The complex action of natural selection produces (i) the adaptations of organisms, (ii) the extinction of species, and (iii) the continuous divergence of characters. The central importance of the theory of natural selection for the full support of the theory of common descent explains the structure of the *Origin* and sheds new light on Darwin's 'long argument'. We see that, after all,

[5] For a similar argument against a Bayesian approach involving a different example, see Chihara (1987).

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Darwin emphasises the evidential structure of his theory, and not only the causal one.[6]

This analysis of Darwin's argument explains two prima facie strange features of the structure of the *Origin*, that Hodge's and Sober's analyses cannot satisfactorily explain: first, the fact that the hypothesis of common descent, as well as the evidence that supports it, are presented in the last part of the book, while the theory of natural selection, which is the cause of evolution, is presented at the beginning. Second, the fact that in the last part of the book natural selection seems not to have a prominent place, as Darwin compares the theory of special creation with the theory of common descent, and not with the theory of evolution by natural selection. Moreover, the current analysis retains some of the positive features of the two previous accounts, and at the same time highlights the unity behind the structure of Darwin's argument (contra Waters 2003). Passages from the *Origin*, as well as the subsequent history of evolutionary thought in the last quarter of the nineteenth century, further support the current assessment of the epistemic situation to which Darwin's overall argument leads.

Darwin has been characterised as the Copernicus of biology: as Copernicus with his heliocentric theory removed the sun from the centre of the universe, so Darwin with the theory of evolution by natural selection removed humanity from its privileged place in nature. It would be more accurate, however, focusing on the structure of Darwin's 'long argument' in the *Origin*, to characterise him as both the Kepler and the Newton of biology: like Newton, Darwin offers causes; but like Kepler, he establishes a new 'given' of natural history, which is none other than the process of branching evolution itself.

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[6] Do the reasons that made Darwin follow this particular method of presenting his theory still apply today? It is important to emphasise that when we today consider the evidence that supports the theory of common ancestry, we are not in the same epistemic situation as a naturalist of the mid-nineteenth century. Today we have a wealth of evidence in favour of evolution at our disposal, unknown in Darwin's time (most crucially, molecular evidence such as the (nearly) universal genetic code). This wealth of evidence makes the inference to common ancestry fully convincing, to an extent not possible one and a half centuries ago.

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