Taking Analogical Inference Seriously: Darwin's Argument From Artificial Selection[1]

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"The question for us," as Ronald Giere writes in Understanding Scientific Reasoning, "is whether analogies play any role in the JUSTIFICATION of [a] new theory." Giere's answer is an emphatic "No." (Giere 1984, pp. 79-80). Although most philosophers of science would probably qualify Giere's unmitigated rejection of analogical justification, few attribute much significance to analogical arguments in science. And when philosophers do grudgingly acknowledge an analogical argument, they are hesitant to analyze it.

Take, for example, Charles Darwin's argument for natural selection. It is difficult to deny that the analogy between artificial and natural selection played an important justificatory role. After all, artificial selection was the topic of the first chapter of Darwin's Origin of Species and was referred to in countless arguments throughout the text.[2] Although some have suggested that Darwin used the analogy to clarify, rather than justify, his theory (for example, Ghiselin 1969), Darwin's own testimony indicates otherwise (see Lloyd 1983). Moreover, as Michael Ruse (1975a and 1979) has explained, analogies played a central role in Herschel's account of scientific justification, an account Darwin is known to have taken very seriously. Despite the importance the analogy must have had in Darwin's justification, few philosophers have tried to unravel the precise way in which Darwin used the analogy to support his theory.[3] It is interesting to compare how much historians have written about the use of analogy in Darwin's discovery with how little philosophers have written about its role in his justification.[4]

I suspect that philosophers have been reluctant to scrutinize Darwin's analogical argument for the very same reason that Giere rejects analogical arguments in general: namely, because there is no philosophically respectable account of inductive inference based on analogies. In short, philosophers of science shy away from analyzing analogical arguments because logicians have not explicated the underlying logic.

I will present a novel account of analogical argument, which has been developed by Julian Weitzenfeld (1984). His account differs from

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traditional ones because it attributes the logical force of analogical arguments to a deductive, rather than inductive, pattern of reasoning. Using Weitzenfeld's account as a guide, I will carry out what I believe is long overdue: an in-depth analysis of how Darwin employed the analogy between artificial and natural selection. That is, I intend to explain how he used the analogy in the Origin of Species to justify his theory of natural selection. Although I would be satisfied to convince you that my analysis of Darwin's analogical reasoning is on the right track, I hope to do more. I hope my analysis will provide a model for taking analogical inference seriously.

Before I present Weitzenfeld's account of analogical inference, let me explain why I believe that traditional accounts fail to capture the logical force behind analogical arguments. Traditional accounts, such as those found in introductory logic texts such as Copi's, typically reconstruct analogical arguments as enumerative inductions of the following special form:

Both A and B have property P(1).
Both A and B have property P(2).
.
.
Both A and B have property P(n).
A has property P(n+1).
Therefore, B has property P(n+1).

Even Mary Hesse (1966), who denounces descriptions which reduce analogical arguments to inductive generalizations, offers an analysis of the logic behind analogical arguments that treats them as if they were simple inductions.[5]

The problem with this type of analysis is that analogical inferences are not based upon a random selection of common properties, but on properties that are associated by the relations that lead us to call the systems (e.g., A and B) analogous. Philosophical accounts of analogical arguments ignore the very relations that make the arguments analogical. Hence, traditional accounts fail to capture the special pattern of reasoning underlying analogical inferences. No wonder these traditional accounts have prompted philosophers to conclude that analogical arguments are too weak to justify scientific hypotheses and to belittle the justificatory role played by them throughout the history of science.

According to Weitzenfeld's account, analogical arguments involve using specific information about an analogue system in order to infer specific information about a system of interest. The inference depends upon a tacit premise that the two systems model isomorphic determining structures. As an example, he considers the realtors' strategy of estimating the fair market value of a house by comparing it to similar houses that have recently sold. When they find an analogue, that is when they find a house whose features match those of the target house, they base their estimate of the value of the target house on the amount for which the analogue sold. According to Weitzenfeld's analysis, this reasoning is based on the tacit premise that the structures responsible for setting the values of the two houses are isomorphic. In this case, the determining structures are assumed to be not just isomorphic but also identical because the houses exist in the same market. Hence, any

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possible factor that would influence the market value of one house would, other things being equal, have the same effect on the market value of the other house. Weitzenfeld says the realtors' strategy assumes that the factors affecting the value of one house can be matched with factors affecting the value of the other (and vice-versa). If the realtors assume that all relevant factors and their quantitative effects on the values of the houses can be matched, it logically follows that the net market values of the houses must also match. Hence, the realtors can determine the market value of a house even though they understand very little about how the determining structure actually determines the value of a house.

The key idea behind Weitzenfeld's analysis, that of isomorphism, can be made clearer by considering the structural relations between two games, 15 and tic-tac-toe. As Weitzenfeld explains, these games are isomorphic. The game of 15 is played by two players with 9 cards numbered one through nine placed face up on the table. The players take turns picking cards and the first to collect three cards whose sum is 15 wins. Everyone, I assume, is familiar with the game of tic-tac-toe. What everyone may not realize is that the moves of tic-tac-toe can be matched with the moves of 15 in a way that will preserve the relation of winning. One such mapping is illustrated below:

2	9	4
7	5	3
6	1	8

(from Weitzenfeld 1984, p. 140).

The mapping represented here preserves the relation of winning in the sense that individual moves of any sequence of moves that would win 15 (e.g., selecting cards numbered 2, 9, and 4) are matched with moves that would win in tic-tac-toe (e.g., marking an 'x' in each space along the top of the tic-tac-toe array). The 'structure' of 15, which includes its elements (i.e., legal moves and players) and the key relation (i.e., winning), is said to be 'isomorphic' to the structure of tic-tac-toe because the elements of one structure can be 'mapped onto' (i.e., put in a one-to-one correspondence with) the elements of the other such that the relation of winning will be preserved. The relation-preserving mapping function is called an 'isomorphism'.

The isomorphism also makes it possible to make deductions about the outcome of a particular game of 15 on the basis of the outcome of a game of tic-tac-toe. For if the outcome of a set of moves in tic-tac-toe was a win, then one could deduce that the corresponding set of moves in the game of 15 would also win.

Weitzenfeld argues, successfully I think, that the "formal core" of an argument from analogy is a valid form of reasoning based on a tacit premise alleging an isomorphism between structures modeled by the analogues. The structure modeled by the system of interest must determine the unknown value of the target variable. The structure modeled by the analogue must determine the value of the variable in the analogue that corresponds to the target variable in the system of

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interest. In the real estate example, for instance, one of the structures must determine the market value of the house in question, the other structure must determine the value of the house upon which the estimate was based (in some cases, the determining structures may be one and the same). Another premise of the formal core involves specific information about the value of the variable in the model that corresponds to the target variable in the system of interest (e.g., the amount for which the analogous house sold). The remaining premises match the values of the determining variables in the structure of interest with the corresponding variables in the analogue (e.g., the number of bedrooms in each house, etc.).

It is the tacit premises concerning isomorphisms, not the argument form, that is the source of unsuccessful arguments. In many cases of analogical reasoning, there is no analogue that matches the system of interest with respect to every variable of the determining structure. For example, realtors usually cannot find a house in the same neighborhood with the same number and kinds of rooms, same type of condition, and so on. In these cases, Weitzenfeld says one constructs a "virtual analogue" by using the closest candidate and adjusting the target value (e.g., house value) for the estimated influences of the contrasting variables. This, of course, is a potential source of error.

Weitzenfeld's account of analogical reasoning does not presuppose that we consciously think about isomorphisms or about virtual analogues; it only suggests that we argue in ways that support tacit premises about such things. Our arguments from analogy are reasonable, according to his account, only if they uphold such premises. Hence, while the premises of the formal core directly concern an isomorphism, the stated premises in analogical arguments may not. If Weitzenfeld's account is correct the stated premises must include statements that would support claims about an isomorphism between structures modeled by the system of interest and its analogue. In particular, they should support the premise that there is an isomorphism as well as identify the pairs of values that are matched by the isomorphism. I call these premises the inductive shell of analogical argument because in general they only inductively lead to the tacit premises that Weitzenfeld says are at the valid core.

Now that I have completed my presentation of Weitzenfeld's account of analogical argument, I will explain the context in which Darwin used his analogical argument from artificial selection. Darwin's theory of natural selection, according to most accounts, includes the following three conditions:

1) Variations are accidentally produced within a species without regard to adaptive advantage.
2) Accidentally produced variations cause differential chances or propensities for organisms to live and reproduce within their environment.
3) Accidentally produced variations are inherited.

As Philip Kitcher (1985) writes, the claim that these conditions are frequently satisfied in nature was not controversial. Darwin's controversial claims were: (1) that the factors alluded to by these conditions could, over many generations, produce modifications of evolutionary magnitude; and (2) that these conditions could be used to

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explain adaptation and many other features of the organic world. In explaining the role of the analogy between artificial and natural selection, it will be useful to distinguish between Darwin's attempt to justify these two claims.

The Origin seems to be loosely organized into three parts, each of which is associated with a separate task. The first part contains four chapters, which discuss in turn, artificial selection, variation in nature, the struggle for existence, and natural selection. In chapters from the middle section of the Origin, Darwin takes up various difficulties in his theory including the apparent absence of transitional forms. In the third part, Darwin exercises the power of his theory to explain "groups of facts" on subjects ranging from embryology to biographical distribution.

Although the analogy between artificial and natural selection is discussed throughout the Origin, it is discussed most fully in the fourth chapter, the one on natural selection. And the primary role of the analogy in this chapter was to help Darwin establish the claim that the factors alluded to by conditions 1 - 3 could, over many generations, produce modifications of the magnitude that separate full-fledged species. It is easy to understand why Darwin had to appeal to the analogy; like the realtor who does not understand just how the complex economic system determines the value of a given house, Darwin had little knowledge of the laws governing the production and inheritance of variations. He had already admitted in the first chapter that the laws of variation were "various, quite unknown, or dimly lit" (Darwin 1859, p. 12) and that the laws governing inheritance were simply "quite unknown." (Darwin 1859, p. 13). Darwin had no theoretical account of why the mechanisms responsible for the production of variations and for their inheritance should support the accumulation of variations over successive generations. But the fact that the mechanisms had supported such an accumulation when man made artificial selections implied that the same should happen with nature's selections: "as man can certainly produce great results by adding up in any given direction mere individual differences, so could Nature . . . ." (Darwin 1859, p. 82).

Darwin's strategy was to match specific information about artificial selection with information about its natural counterpart in order to infer that the results of the two processes must also correspond. Darwin's argument depended upon matching the elements of artificial and natural selection as follows:

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Artificial Selection	Natural Selection
Variations produced (through an unknown mechanism)	Variations produced (through an unknown mechanism)
Man selects variations (by conscious effort but sometimes by unconscious means)	Nature selects variations (by providing conditions that give organisms with certain variations a better chance to live and reproduce)
Variations inherited (through an unknown mechanism)	Variations inherited (through an unknown mechanism)
Production of domestic races	Production of natural counterpart to domestic races which, Darwin inferred, were full-fledged species

Since the determining mechanisms for the production and inheritance of variations was the same for both artificial and natural selection, Darwin could safely assume that the determining structures were isomorphic. Less straight forward was the matching of elements from artificial selection with those from natural selection.

Darwin devoted much care to comparing the way man made selections with the way selections were made in nature. And although most readers assume that Darwin based his analogical argument on an analogy from the results of conscious efforts of man, he also appealed to a different kind of artificial selection:

> In man's methodical selection, a breeder selects some definite object, and free intercrossing will wholly stop his work. But when many men, without intending to alter the breed, have a nearly common standard of perfection, and all try to get and breed from the best animals, much improvement and modification surely but slowly follow from this unconscious process of selection, notwithstanding a large amount of crossing with inferior animals. Thus it will be in nature; (Darwin 1859, p. 102).

Darwin had already established in the first chapter that unconscious selection had resulted in significant modification of plants and animals under domestication. Hence, even though natural selection "will always act with extreme slowness" and "often be greatly retarded by free intercrossing", Darwin had reason to believe it could still result in significant modification.

Darwin's analogical inference depended not just upon matching the determining variables (i.e. the inputs — e.g. selections made under domestication and in nature), but also the determined variables (the outputs — domestic varieties and natural species). Darwin adopted a

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dual strategy: first, he argued that the differences between domestic races and natural species were not as great as many assumed (see pp. 13-16) and then he reasoned that the actual differences could easily be accounted for by the differences in the way selections were made:

> As man can produce and certainly has produced a great result by his methodical and unconscious means of selection, what may not nature effect? Man can act only on external and visible characters . . . [nature] can act on every internal organ, on every shade of constitutional difference, on the whole machinery of life . . . . How fleeting are the wishes and efforts of man! how short his time! and consequently how poor will his products be, compared with those accumulated by nature during whole geological periods. Can we wonder, then, that nature's productions should be far "truer" in character than man's productions . . . ? (Darwin 1859, pp. 83-84).

In a sense, Darwin was estimating what would result if man could make the same kinds of selections that were made in nature. That is, he was tacitly considering what Weitzenfeld referred to as a "virtual analogue". In the Sketch of 1842, an early and unpublished precursor of the Origin, Darwin explicitly imagined just such a virtual analogue:

> . . . if a being infinitely more sagacious than man (not an omniscient creator) during thousands and thousands of years were to select all the variations which tended towards a certain ends . . . . Who, seeing how plants vary in a garden, what blind foolish man has done in a few years, will deny an all-seeing being in thousands of years could effect . . . . (Darwin 1842, p. 6).

Although the primary purpose of the analogy within the chapter on natural selection was to establish his claim that natural selection could produce significant modifications, in later chapters, the analogy was used to help establish the second controversial claim associated with the Origin; namely, that natural selection and the theory of descent could be used to explain many groups of facts. In other words, the analogy extended the explanatory power of Darwin's theory.

Among the phenomena which Darwin tried to explain by employing the analogy between artificial and natural selection was the following generalization, which he attributed to G. R. Waterhouse:

> A part developed in any species in an extraordinary degree or manner, in comparison with the same part in allied species, tends to be highly variable. (Darwin 1859, p. 150).

Darwin went on to explain that this rule only held for structures that were extraordinary with respect to closely related species. The wing of a bat, he noted, while extraordinary with respect to the class of mammalia, do not count because there are a number of closely related (bat) species with respect to which wings are not unusual.

After substantiating this law with evidence from his own barnacle research as well as from the observations of others, Darwin asked why it should be true:

> On the view that each species has been independently created, with

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> all its parts as we now see them, I can see no explanation. But on the view that groups of species have descended from other species, and have been modified through natural selection, I think we can obtain some light. (Darwin 1859, p. 152).

Darwin then argued from artificial selection. He noted that when artificial selection is applied to bring about rapid transformation of certain parts of a domestic breed, those parts are "eminently liable to variation". He provided illustrations and then remarked that there is a constant struggle between "on the one hand, the tendency to reversion to a less modified state, as well as an innate tendency to further variability of all kinds, and on the other hand, the power of steady selection to keep the breed true." (Darwin 1859 pp. 152-153). Man's persistent selection will eventually win, Darwin maintained, but while the animals are being modified, the parts undergoing rapid change will vary to a great extent.

Darwin went on to consider the natural situation. Matching the relevant elements in nature to the ones in the domestic model, he reasoned that when a part has been developed by natural selection in an extraordinary manner in one species relative to closely related species, it must have undergone modification quite recently. For if it wasn't recently modified, the organisms that originally had the adapted part would have given rise to a number of closely related species. He further suggested that if the part was recently modified, the struggle between "natural selection on the one hand, and the tendency to reversion and variability on the other hand" may not be over. So, Darwin concluded, "we might, as a general rule, expect still to find more variability in such parts than in other parts of the organisation, which have remained for a much longer period nearly constant." (Darwin 1859, p. 153).

Darwin's argument rested squarely on the analogy. Without the model of domestic selection, he would not have been able to establish the principle that there is a tendency for reversion and variability in parts being modified by selective processes; for he did not have a theory about the causal mechanism underlying variation from which he could infer the principle. He reasoned that since the selective acts of man and nature interact in similar ways with the same laws of variation, the results should also be similar.

Thus, Darwin used the analogy between artificial and natural selection to expand the explanatory power of his theory as well as to establish the efficacy of natural selection. My analysis of how Darwin employed the analogy to bolster his case for natural selection would be incomplete if I didn't explain another dimension of his treatment of artificial selection. The third way Darwin used the analogy, however, didn't involve a direct analogical inference (as did the roles described above); rather, it was related to making the revisionist agenda of the Origin more palatable.

Kitcher (1985) has argued, very convincingly I think, that Darwin's real achievement was not to establish a set of statements about the biological world; what Darwin accomplished was nothing less than a radical revision in the practice of biology. Darwin managed to convince his colleagues to take up new problems and work on solving them by adopting various problem-solving strategies presented in the Origin. The

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third role that artificial selection played was to help establish the legitimacy of certain kinds of problems and problem-solving strategies.

For example, Darwin devoted nearly ten pages to tracing the ancestry of domestic pigeons. By starting with what must have seemed to be a perfectly respectable problem, even according to the orthodox standards of his day, Darwin was able to display the effectiveness of his problem-solving strategies without relating them to the controversial issue of evolution. In addition, Darwin's denunciation of those who took the "doctrine of the origin of our several domestic races from several aboriginal stocks" to the "absurd extreme" seems nothing more than a thinly-veiled anticipation of the attack he was preparing to launch against the independent creationists:

> They believe that every race which breeds true, let the distinctive characters be ever so slight, has had its wild prototype. At this rate there must have existed at least a score of species of wild cattle, as many sheep, and several goats in Europe alone, and several even within Great Britain. One author believes that there formerly existed in Great Britain eleven wild species of sheep peculiar to it! (Darwin 1859, p. 19).

Intentional or not, the effect of successfully applying his problem-solving strategies on problems that seemed uncontroversial must have led readers to think that analogous problems concerning natural varieties and analogous strategies for solving them could be legitimate parts of scientific practice. The fact that the problems concerning domestic varieties could not be solved on views analogous to independent creationism must have made his general views even more persuasive.

Darwin used the analogy between natural and artificial selection to help justify his theory of natural selection in three ways. First, he used it as a polemical device to lure his readers into the new practice of biology. He accomplished this by introducing new types of problems and strategies for solving them in the uncontroversial context of the modification of domesticated plants and animals. Second, he tried to infer that the result of nature making selections over many generations would be significant modification. He based this inference on the assumption that the structure determining the modification of organisms by artificial selection was isomorphic to its natural counterpart. Then, adjusting for the differences between the way nature and men make their selections, he inferred that the selections made by nature should produce modifications as significant as those distinguishing full-fledged species. And third, Darwin increased the explanatory power of his theory by inferring that the trends produced by artificial selection should have their corollaries in nature.

In answer to the skeptics of analogical argument, I think we should say that analogical reasoning played a key role in Darwin's justification of his theory. One merely has to imagine how much weaker Darwin's case for natural selection would have been, if he had not been able to appeal to its artificial counterpart.

Notes

[1]I thank Fred Churchill and Michael Ruse for helpful comments on an early ancestor of this paper.

[2]Young (1971) has described the prominence of the analogy in Darwin's argumentation and masterfully related Darwin's use of the analogy to a broad intellectual context.

[3]One notable exception is Ruse's (1975b) analysis. He argues that the analogy served to justify the existence of favorable variations in nature. I disagree. Darwin demonstrated the existence of favorable variations by showing that the struggle for existence involved such a delicate balance that the kinds of variations observed in nature could tip the balance in favor of their bearers.

[4]The question of what role, if any, was played by the analogy between artificial and natural selection in Darwin's discovery has been treated in-depth within the following works: Herbert (1971), Kohn (1980), Limoges (1970), Ospovat (1981), Schweber (1977), Ruse (1975b and 1979), and Vorzimmer (1969a and 1969b). The role the analogy played in the justification of Darwin's theory has received far less scrutiny. While historians have done an admirable job describing the general context of the analogy in Darwin's justification (especially Young 1971 and Evans 1984), only Ruse (1975c) has tried to analyze just how the argument worked (see note 3). Lloyd (1983) and Kitcher (1985) devote only about a page apiece to the analogy in their analyses of Darwin's justification.

[5]Hesse separates her description of analogical arguments from her justification of them. While her illuminating description accounts for the special kinds of relations that prompt us to call two systems analogous, her justification does not take these special relations into account. See Hesse (1966, pp. 101-129).

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