The Logical Skeleton of Darwin's Historical Methodology

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An apparently peculiar form of explanation is found in evolutionary biology (and other historical fields); it is called a genetic explanation by Beckner (1959) (and, in a more general discussion, by Hempel (1965)), a narrative explanation by Goudge (1961), and a Darwinian history by Kitcher (1985). Kitcher, assuming that the Darwinian history has some kind of logically respectable structure, is primarily concerned with arguing that it is the cornerstone of Darwin's historical methodology; Beckner and Goudge, on the other hand, assuming that the genetic (or narrative) explanation is an important part of evolutionary biology, are primarily concerned with the difficulty of fitting this form of explanation into a logically respectable structure. Adopting the narrative explanation terminology, and assuming that the narrative explanation is central to Darwin's historical methodology and to the methodology of contemporary evolutionary biology, I will in this paper delineate its logically respectable structure.

This delineation will also cast some light on the problem pointed out by Hull (1975). He avoids a direct challenge to the logical respectability of narrative explanations, but asserts that the explanatory content of narrative explanations (particularly in history, but also apparently in evolutionary biology) is greater than can be accounted for by reference to the (frequently weak) laws to which they appeal; he claims that "The integration of an element into an overall pattern can impart as much intellectual satisfaction as the subsumption of a particular under a scientific law." (1975, p. 274). The analysis given in this paper will give some insight into how an element is integrated into an overall pattern via narrative explanations.

1. Preliminary Description of Narrative Explanations

A narrative explanation in evolutionary biology seeks to explain the origin of a particular suite of traits in a descendant taxon by showing how the known traits of an ancient taxon could have been, and (it is hypothesized) were, modified by natural selection to give rise to the specified suite of traits. It does this by giving a set of selection scenarios indicating sequences of selection events which delineate how each (or, usually, the most important) of the traits could have

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evolved. The purpose of the statements in a narrative explanation is

1) to describe the traits, lifestyle or environment of an ancestral taxon which would cause a small change toward the traits of the descendant taxon to be selected for, or

2) to present supporting evidence for the existence or causal efficacy of the traits, lifestyle and environment thus described.

For particular narrative explanations there is usually too little supporting evidence to support a strong conclusion that the traits did evolve in the way specified, so the statements frequently contain "hedges" such as "may have occurred", "appear to have evolved", etc.. But the fact that supporting evidence is offered to the extent it is shows that these narratives are not mere stories; and the type of supporting evidence that is offered shows that they involve instantiations of laws. Thus narrative explanations are covering law explanations.

I shall use the deductive-nomological (D-N) model as my covering law model. This enables me to give a characterization of the structure of narrative explanation in evolutionary biology which is explicit enough to enable those who prefer different models to determine whether my points are transferable to their models. (Since my models, though in some ways very explicit, are still explanation sketches and neglect probabilistic factors, even Hempelians will have to make such determinations.) More importantly, the explicitness of the D-N model reveals a significant feature of the structure which might fail to be noticed if a less explicit explanation model were used.

Let us now look at a particular narrative explanation in order to check this description.

2. Example: Evolution of Amphibians

Because a narrative explanation involves a set of sequences of selection scenarios, it cannot be brief if a reasonable amount of supporting evidence is offered. Consequently examples that are brief enough to analyze briefly either will have little supporting evidence or will concentrate on a single one of the selection scenarios. The example Goudge uses is Romer's 1941 discussion of the origin of the amphibians from fishes, which offers little supporting evidence. I shall piece together bits of the same narrative from Romer's 1955 comparative anatomy textbook; this will indicate some of the evidence that was behind his 1941 narrative, and will give enough detail to allow insight into the structure of the selection scenarios.

> Greatest, perhaps, of all ventures made by the vertebrates during their long history was the development of tetrapods in the invasion of the land -- a step which involved major changes in function and resulted in profound structural modifications. The shifts from swimming to four-footed walking, and from gill breathing to the dominance of lungs, are the most obvious of the modifications necessary in this step. But analysis shows that functional and structural changes were necessitated in almost every organ or organ system of the body. (Romer 1955, p. 54).

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> Lungs appear to have been present in all primitive bony fishes... . Lungs were presumably an aid to survival under conditions of seasonal drought; such conditions may have been present in the fresh waters in which the ancestral Osteichthyes lived.
>
> ... .
>
> From the viewpoint of the descent of land animals the choanichthyes are the most important of the two [subclasses], for they contain the order Crossopterygii, from which land vertebrates appear to have descended... . The Choanichthyes may have, in contrast to the other subclass, internal nostrils associated with lung breathing (the name refers to this feature), fleshy-lobed fins (suitable for development into land limbs)... . (p. 45).
>
> The amphibians appear to have evolved from crossopterygian ancestors toward the close of the Devonian, an age during which seasonal droughts were, it seems, common over much of the earth. Lungs are an excellent adaptation for use under stagnant water conditions. But when a stream or pool dries up completely, a typical fish is rendered immobile and dies. Some further development of the fleshy fins already present in crossopterygians would give their fortunate possessor the chance of crawling up or down the stream bed (albeit with considerable pain and effort at first) and enable him to reach some surviving water body where he could resume a normal piscine existence.
>
> Legs, the diagnostic feature of the tetrapod, may thus have been, to begin with, only another improvement for an aquatic life. The earliest amphibian was little more than a four-legged fish. Life on land would have been the farthest thing from his thoughts (had he had any). It was probably only after a long period of time that his descendants began to explore the possibilities of land existence opened out before them through their new locomotor abilities. (pp. 57-58).

Notice that in this excerpt Romer mentions that the origin of the amphibians involved structural changes in almost every organ of the body, although he offers a selection scenario only for the development of the land limbs.

The following generic explanation indicates the deductive-nomological form underlying Romer's narrative and indicates the support Romer offers for the truth of the conditions.

Generic Explanation for Development of Land Limbs Scenario

Laws:

> Laws used in determining the proximate effects of particular traits (e.g., laws of physics which determine the mechanical efficiency of particular skeletal structures for walking on land).
> Laws of natural selection and heredity.

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Fixation law (derived from laws of natural selection as stated in Williams (1970)):

If (1) the population S has a subclan, SY, with trait Y,
(2) organisms with trait Y have a greater than average fitness in conditions X,
(3) conditions X occur regularly in the environment of S,
(4) trait Y has no equivalent disadvantages in other regularly occurring environmental conditions of S, and
(5) trait Y has a hereditary basis

then SY will expand until it is fixed in S.

Conditions:

Conditions showing the selective value of the indicated change:

A. Seasonal droughts causing streams and pools to dry up occurred regularly during the Devonian. (Support: geological record indicating drought plus observation of present-day consequences of drought.)

B. When small streams and pools dry up during a drought there are frequently other nearby pools and streams which have not dried up. (Support: observation of present-day droughts.)

C. "When a stream or pool dries up completely, a typical fish is rendered immobile and dies." (p. 57). (Support: obviously from present-day observation.)

D. The reaction (e.g., dying struggles) of a fish under the stress of too little water would occasionally propel it onto land and into another puddle. (Support: some present-day observation plus a thought experiment using the fleshy-lobed fins of the Crossopterygians.)

Condition specifying the initial condition of the trait and relevant related traits:

E. Fish with primitive lungs and fleshy-lobed fins were common in the Devonian. (Support: fossil record.)

Condition specifying the presence of the necessary variability:

F. A mutation occurred which further developed the ability of the fleshy-lobed fins to function as land limbs. (Support: assumed.)

Deduced result: The mutation became a characteristic of the species so that the species has more efficient land limbs as a result of this selection process.

3. The Use of Generic Explanations in a Narrative Explanation

The above generic explanation is a sketch of a D-N explanation of the fixation of a single mutation which makes whatever limbs the population has slightly more efficient on land. To explain the fixation of the multitude of genes which together generate efficient land limbs would require a multitude of similar D-N explanations. Rather than attempt to give separate explanations for the fixation of each mutation, the biologist separates the mutations into classes of mutations with similar effects (e.g., the class of mutations which make limbs more efficient as land limbs, the class of mutations which make air breathing more efficient, etc.) and which are in similar environments and then gives a general D-N explanation for each class;

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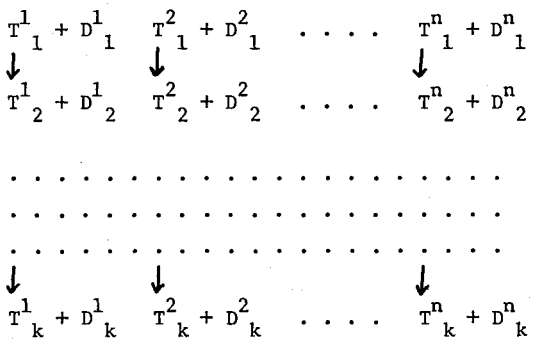
I call such an explanation a generic explanation. Thus the explanation of each actual fixation of a mutation increasing efficiency as land limbs is an instantiation of the generic explanation given above.

Usually a narrative explanation will have two or more generic explanations, one for each of a suite of complementary traits; for example, the land-limb generic explanation would be complemented by an air-breathing generic explanation and an amphibian-skin generic explanation. The narrative explanation would then be sets of instantiations, by different mutations, of the different generic explanations. (I am, of course, describing the underlying structure of the narrative explanation; in any particular case the biologist will sketch in some of the features, allude to others, and completely neglect others. But all biologists know that any particular explanation is only a sketch; the evidence for the accuracy of my description lies not merely in its relationship to actual explanations but also in the amount and kind of support that biologists demand when two competing narrative explanations have been offered. See, e.g., the arguments offered in Ostrom (1974), Ostrom (1979), Koopmans (1979), Lackey (1979), and Borrowsky (1979).)

How are these separate generic explanations integrated to form a single narrative explanation? Note that the selective value of a mutation depends on which other mutations have already been fixed (e.g., the selective value of a muscle strengthening mutation is dependent on what bone strengthening mutations have already been fixed, and also of what air breathing mutations have already been fixed); because of this, the narrative explanation is not merely a set of instantiations of the generic explanations, it is a set of sequences of instantiations of the generic explanations. This is illustrated by the following diagram:



where T^i_j designates the state of a trait of type i (e.g., an air-breathing trait) at the j^{th} stage in the sequence of D-N explanations, and D^i_j designates the conditions and laws used in the j^{th} stage of explanations of the type i trait. Among the conditions in D^i_j are the states of all traits at stage j-1.

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In this set of sequences of D-N explanations, for any j, explanation n is connected to the previous explanations in the sequence by the fact that the conclusion of the previous explanations (that particular mutations have been fixed) appears as a condition of explanation n. Thus it is a multidimensional set of recursive sequences of D-N explanations.

4. Comparison of This Analysis with Previous Analyses

This analysis illuminates previous published analyses of narrative explanation in several ways: By explicitly stating the selection law (the Fixation Law) used, it refutes Goudge's (1961) claim that narrative explanations use no laws. By giving examples of how independent evidence for the subsidiary hypotheses is found, it refutes Beckner's (1959) claim that narrative explanations were not even sketches of covering law explanations, since "no independent evidence that the subsidiary hypotheses are indeed exemplified" (1959, p. 108) is required. (A more definitive refutation would have been possible if there were space to discuss the bird flight example to which the reader was referred above; this shows that whenever a subsidiary hypothesis becomes controversial, biologists demand, and examine carefully, independent evidence for the subsidiary hypothesis.) By delineating the multidimensional recursive nature of the explanation, my analysis gives some insight into how a narrative explanation integrates an element into an overall pattern, thus illuminating a source of the intellectual satisfaction which Hull (1975) claims is imparted by such integration. By delineating the multidimensional nature of these explanations, my analysis extends the unidimensional analysis given by Hempel (1965). And by delineating in some detail the structure of these explanations, my analysis cashes out the promissory note given by Kitcher (1985) in his references to Darwinian histories as "schemata" for answering questions.

5. Conclusion

This investigation of the structure of narrative explanations in evolutionary biology reveals that:

1) narrative explanations do have a deductive-nomological base, but that
2) their structure contains two significant additional elements as well.

The additional elements are:

(a) the multidimensional recursive connection between the different sub-explanations in a narrative explanation,
(b) a set of generic explanations which make possible the integration of multiple co-existing processes.

We must conclude that narrative explanations of evolutionary biology cannot be subsumed under the D-N model, since an important part of their explanatory force comes from a logical feature which is external to this model. The model suggested in this paper for narrative explanations is in fact an extension of the D-N model. From this we might conclude that the explanations of physics and chemistry, whose structure is purportedly captured by the D-N model, are different in a significant sense from narrative explanations; I am reluctant to draw this conclusion since at least some chemical explanations seem to have

a significant multidimensional recursive feature. But at least this discussion indicates that a general model of scientific explanation must allow for a multidimensional recursive feature as an irreducible element of a scientific explanation.

Does this discussion also have significant implications for historical explanations in general? Certainly historical explanations are typically multidimensionally recursive. Probably historical explanations generally make use of generic explanations similar to those described. But are there in general historical laws which function as does the Fixation Law in the Darwinian generic explanations? If "historical" is taken in its sense of "pertaining to human history", there are at present no good candidates for the honor of being such a law; but if such laws exist, the analysis given in this paper might, by clarifying the structure within which they work, make it easier to find them.

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