Chapter 3

Explanations in Systematics

Walter J. Bock

Milestones in Systematics 2004
The Systematics Association Special Volume Series 67
David M. Williams and Peter L. Forey, editors
CRC Press, Boca Raton, Florida

Abstract

Not all of evolutionary biology is historical, but rather contains both nomological-deductive explanations (N-DEs) and historical-narrative explanations (H-NEs); hence one must be careful to ascertain the proper type of explanation to use in the different parts of evolutionary studies. Of the five major areas of evolutionary theory outlined by Mayr, four are N-DEs, and only the one dealing with Darwinian evolutionary classification, Haeckelian phylogenies, Hennigian cladifications, evolutionary histories of attributes and groups of organisms and historical biogeographies is historical in nature, with the explanations being historical-narrative. Philosophers of science have largely shied away from consideration of H-NEs and how they are connected to underlying N-DEs. An overview of H-NEs is presented in which it is shown that each such explanation deals only with a singular event and cannot be considered to deal with universals as do N-DEs. Moreover, it is argued that careful attention must be given to the degree of confidence of each H-NE and that most of these explanations have a poor to medium degree of confidence. Care must be taken not to overstate the robustness of the methods and conclusions of H-NEs in evolutionary biology.

Introduction

At the first International Congress of Systematics and Evolution held in Boulder, Colorado in August 1973, I introduced, for better or worse, some of the philosophical ideas of Karl Popper into biological systematic discussions (Bock, 1974). In doing so, I had two major concerns. First, I wished to stress that biological classifications, phylogenies and evolutionary histories of all kinds are theoretical scientific statements, and as such they had to be tested against objective empirical observations, with care taken to clarify the exact nature of the objective empirical observations used to test these different theoretical statements. Second, I was concerned with the demarcation between natural science and nonscience because of the rise of scientific creationism and the arguments advocated by the proponents of scientific creationism against evolutionary biology in its broadest sense, including the classification of organisms. Acknowledging the objections raised by some philosophers against the Popperian demarcation of science as that endeavor of humans in which theoretical statements are potentially able to be disproved by testing them against objective empirical observations, I feel that this criterion provides the best demarcation between evolutionary biology and all forms of antievolution, including scientific creationism.

Nevertheless, when introducing Popper's ideas into evolutionary and systematic thinking, I was greatly worried about certain aspects of theories in evolutionary biology, although I did not express this disquiet in my talk or published paper. I was aware that not all of

0-415-28032-X/04/$0.00+$1.50

evolutionary biology was historical in nature, as concluded by many philosophers and biologists (see Bock and von Wahlert, 1963), and that the nature of most empirical tests used for theoretical explanations in systematics differed from those advocated by Popper (Bock, 1977). Popper's central, and perhaps only, interest in science was in the realm of nomological-deductive explanations (N-DEs) and not in any historical areas, such as historical-narrative explanations (H-NEs). The major approach to testing in H-NEs appears to be induction, and for Popper even the slightest whiff of induction in tests of scientific theories was a complete no-no. Yet, I felt that there were certain significant advantages in the introduction of Popperian ideas into systematic biological thinking.

It was nevertheless a complete surprise to me that the Popperian approach to philosophy was almost immediately and strongly, indeed fully, accepted by systematists advocating a cladistic approach to systematics. For cladists, in the 1970s and 1980s, Popper's ideas about science and scientific methods provided the foundation for their entire methodology, including the support for the form of a cladistic classification and the way in which these classifications are tested against empirical observations (see Platnick and Gaffney, 1977, 1978a, 1978b). This acceptance of Popper's ideas was well prior to the rise of transformed cladistics, contrary to Hull's statement (1999:498) that this acceptance came much later. To my knowledge, cladists still accept Popper's approach to the philosophy of science as the foundation for their methods and conclusions in cladistics; I am not aware of any rejection or contrary position proposed by any cladist (but see Rieppel, Chapter 4).

Systematics involves a number of ordering systems, but not all ordering systems are classifications (Mayr and Bock, 2002). Moreover although ordering systems such as Darwinian classifications, Haeckelian phylogenies and Hennigian cladifications are H-NEs, not all biological classifications are H-NEs. Typological or near-typological biological classifications, such as those for cell, tissue and organ types or for ecological communities, are N-DEs (Mayr and Bock, 2002:171) and must be treated quite differently.

I welcome the opportunity of being asked to participate in this symposium and to provide a review of explanations in evolutionary biology, especially in classification and phylogeny, and of the role of Popperian concepts in the philosophy of science for methods and explanations in systematics. I thank the organizers for inviting me to take part in the symposium and contribute a paper to the published volume.

Fields within Evolutionary Biology

A major difficulty in considering types of explanations within evolutionary biology is that most philosophers and biologists do not have a clear understanding of the diversity of fields of study within evolutionary biology, or precisely what is meant by the theory of evolution. This difficulty started in 1859 with the publication of Darwin's *On the Origin of Species* (Darwin, 1859). Darwin spoke of "my theory" — always in the singular. Hence the widespread, but erroneous conception that only a single type of theory exists in evolutionary biology. Since evolution is about the history of life, most biologists and philosophers consider all of evolutionary theory, including classification and phylogeny, to be historical in nature. However, cladists, in accepting the Popperian approach as the basic philosophical foundation for their work have, knowingly or unknowingly, accepted the position that at least this aspect of evolutionary biology is nomological-deductive in nature. After considering the complex nature of Darwin's theory, I will consider types of explanations existing in science and how these explanations apply to the diverse aspects of evolutionary biology.

Darwin's theory of evolution as originally advocated in his *On the Origin of Species* (1859) is actually a bundle of five separate but interrelated theories (Mayr, 1985). These five separate theories found in Darwin's 1859 book can still characterize areas within evolutionary biology today; these are:

a. **Evolution as such** is the theory that states that all populations of organisms are changing over time, with the minimum time period being one generation. The theory is clearly nomological-deductive.
b. **Common descent** implies that all species or populations of organisms have descended with modification from common ancestors; this descent includes both modification and branching. Darwinian common descent is equivalent to Haeckel's (1866) phylogeny. Hennigian phylogeny is equal only to the branching aspect of Haeckelian phylogeny (Mayr and Bock, 2002). Common descent is expressed in Darwinian classifications, Haeckelian dendrograms and Hennigian cladograms, which are all clearly theoretical statements. These theories, as well as all other theoretical statements about the history of organisms, such as conclusions about the evolution of organic features (e.g., the avian wing) and historical biogeography, are H-NEs.
c. **Gradualism** is the idea that evolutionary change takes place in steps of the magnitude seen between parents and offspring and never in large sudden saltations or jumps. Evolutionary jumps do not take place between species or taxa of higher levels such as expressed in the idea that the first bird hatched from a reptilian egg. Again this theory is nomological-deductive.
d. **Multiplication of species** states that there is splitting of phylogenetic lineages as well as transformational change within a lineage. Hence evolutionary change includes two processes — phyletic evolution or transformation and speciation. Some workers would include extinction as a third process and others would include extinction under phyletic evolution. This theory is also nomological-deductive.
e. **Natural selection** is Darwin's mechanism for phyletic transformation. Today this would be expressed as causes or mechanisms of evolutionary change, regardless of the diverse causes that different evolutionists would include; this theory is clearly nomological-deductive.

Thus it is clear that evolutionary theory or evolutionary biology is not just historical (see Bock and von Wahlert, 1963) and indeed that most aspects of evolutionary theory are not historical, but nomological-deductive. Many evolutionary biologists, especially systematists, work in area b (common descent) dealing with historical evolutionary theory. This paper emphasizes historical evolutionary theory and how this is based on nomological evolutionary theory.

Popper and Historical Analyses

Since the publication over a quarter of a century ago of my original paper "Philosophical Foundations of Classical Evolutionary Classification," I have become increasingly interested in systems of explanation in science and especially in evolutionary biology (see Bock, 1978, 1981, 1988, 1991, 1992, 2000; Szalay and Bock, 1991). This was prompted by concerns in 1974 when I introduced into systematics Popper's ideas that the nature of explanation and the methods of testing theoretical statements in classification and phylogeny do not fit easily or at all into the Popperian mold.

There was also the matter of the frequently expressed accusation that Popper claimed that all of evolutionary biology was historical and hence nonscientific and that he had subsequently recanted this claim. This claim appeared to stem from Popper's (1957; see especially pp. 105–119) *The Poverty of Historicism*. If one reads this volume carefully, it is clear that Popper makes the error of regarding all aspects of evolutionary theory or evolutionary biology as historical, which would make it impossible to formulate general laws about evolution similar to those in physics and chemistry. It is equally clear that Popper's position is quite definite (1957:143) that "*history is characterized by its interest in actual,*

singular, or specific events, rather than its laws or generalizations" (italics in the original) and that law-like generalizations cannot be derived from historical analyses (1957:143–147).

The presentations in Popper's *The Poverty of Historicism* cannot be taken as meaning that he does not consider evolutionary theory to be nonscientific, but only as a lack of appreciation of the full range of thinking in evolutionary biology. Many other philosophers and biologists are also guilty of this misconception. Moreover, as many other philosophers, Popper did not appreciate the details of H-NEs in science and their relationship to N-DEs. It is clear, however, that because classification, evolution and phylogeny of groups of organisms deal with singular events, Popperian ideas about the philosophy of science cannot be used for their analysis (see also Hull, 1999:383).

Hull (1999) has performed an important service in his analysis of Popperian ideas and their relationship to biology and especially evolutionary biology. Hull's analysis would have been clearer had he included a discussion of Darwin's five theories and thereby provided a clarification of which parts of evolutionary theory are historical and which are not. Nevertheless, Hull points out (1999:498) that it is ironic that cladists have adopted Popperian ideas because of Popper's absolute stance against induction in scientific testing and against the notion that there are theory-free facts.

Explanations in Science

Philosophers of science are especially interested in scientific explanations, but almost all of their analyses have been based on sciences such as physics. Unfortunately, as I have expressed earlier (Bock 2000:33), "... the physical sciences are rather simple compared to the biological sciences and that any philosophy of science based solely on the physical sciences is too simplistic to be realistic." This is because physicists have delimited their science so that it is completely nonhistorical. The standard model for explanations in science is the N-DE, which comes under a number of names such as hypothetical-deductive, covering law, nomological, etc. This is the model advocated by Popper, and hence in accepting Popper's ideas as the foundation for their work, cladists claim that they are advocating N-DEs for their scientific methods and conclusions. However, in some sciences, such as biology and geology, there is a major historical aspect that has to be included in scientific explanations. Philosophers of science have either shied away from historical explanations in science or, if they consider them at all as does Hempel (1965:Ch. 9), they waffle on the details of these explanations.

Two different, but interrelated systems of explanations exist in biology, which are (a) the dichotomy of N-DEs versus H-NEs, and (b) the dichotomy of functional explanations versus evolutionary explanations. The latter system stems from the division of biology into the major areas of functional and evolutionary biology (Mayr, 1982). These two systems of explanations in biology do not have a simple relationship to one another. All functional explanations are N-DEs and all H-NEs are evolutionary, but evolutionary explanations can be either N-DEs or H-NEs. Hence it is essential not only to characterize carefully the properties of N-DEs and H-NEs, but to show which parts of biology, and especially of evolutionary biology, are nomological-deductive and which are historical narrative.

Nomological-Deductive Explanations (N-DEs)

N-DEs are the standard form of explanation in science and take the following form. Given a set of facts (e.g., initial and boundary conditions) and a set of laws (be they causes, processes, or outcomes; see Bock 1993), both of which form the explanatory sentence, or *explanans*, a particular conclusion, or *explanandum*, follows (Hempel and Oppenheim 1948; Hempel 1965:335-338). N-DEs answer the question, how has a particular phenomenon [*explanandum*] occurred? N-DEs apply to universals (nonlimited sets of phenomena) and

do not depend on the past history of the objects or the phenomena being explained, and their premises (the nomological statements) are assumed to be always true. Saying that N-DEs apply to universals means these explanations are not temporally-spatially restricted within the proper region of the phenomena, which for biology is the earth, and more specifically the surface (i.e., the upper part of the crust) of the earth.

If an *explanandum*, resulting from the conjunction of the set of facts invoked (initial and boundary conditions) and the set of general laws, disagrees with empirical observations, then the N-DE is not valid (i.e, falsified), and one must search for the reason for the falsification. Falsification means that the *explanandum* does not agree with independent, objective, empirical observations, but falsification does not automatically imply that the general laws used in the explanation are in error, although this is a possibility. Possibly, the set of initial or boundary conditions used in the empirical test was in error, or the empirical observations were in error. Examples of N-DEs include clarification of oceanic tides using gravitational laws and of phyletic evolution evoking natural selection (nonrandom, differential survival and reproduction of organisms).

Historical-Narrative Explanations (H-NEs)

H-NEs provide an understanding of the existing attributes of a particular set of objects or phenomena at a specified time; these explanations depend on the past history of these objects, and they must use pertinent N-DEs. The objects explained by an H-NE are singulars, not universals, and have definite spatial-temporal positions. H-NEs are stated on a nondeductive and probabilistic basis with the hope of reaching the most reasonable and probable explanation for the objects studied. Five aspects of H-NEs are stressed, the first being the most important:

1. These explanations are historical, which means that earlier events affect later events. Consequently in any H-NE, special care must be given to formulating the analysis within the correct chronological order of events and changes.
2. H-NEs are given on a probability basis of being correct (Nagel, 1961:26). This is necessary because these explanations frequently involve a number of often conflicting N-DEs employed in the explanation and because of the uncertainty over initial and boundary conditions involved in the explanation.
3. H-NEs must be based on pertinent N-DEs, and these N-DEs, together with the pertinent empirical observations, form part of the chain of arguments used in testing the H-NE.
4. H-NEs are not general, in that a successful explanation for one phenomenon (e.g., origin of homoiothermy in mammals) need not hold for a similar phenomenon (e.g., avian homoiothermy).
5. Because of their complexity, the possible confusion between conflicting explanations and the difficulty in identifying valid confirming or falsifying tests, H-NEs must be stated clearly and unambiguously. Failure to do this may preclude meaningful tests or appraisal of rival H-NEs.

H-NEs in biology include the evolution, phylogeny and classification of organisms or the evolutionary history of their attributes — that is, anything related to the history of life.

Being theoretical scientific statements, H-NEs are available to tests by falsification, but such tests are often extremely difficult and inconclusive. Generally H-NEs are not tested by falsification (in spite of numerous statements in the literature) but usually by confirmation with the addition of more and more corroborating support. This procedure is closely akin, if not identical, to induction in the strict sense of that concept. Objections cannot be raised to inductive testing of H-NEs because they are theoretical statements about a finite number

of objects, in contrast to N-DEs, which cover universals or an unlimited number of objects. Testing of H-NEs depends on argument chains involving pertinent N-DEs and a large number of background assumptions (hypotheses, many being initial and boundary conditions), and they are finally tested against objective empirical observations. One should proceed to the empirical observations as directly as possible, although the argument chain is often complex. The empirical observations and their roles as tests, whether falsifying or confirming, should be designated clearly.

What makes H-NEs scientific is point 3 (above), that "H-NEs must be based on pertinent N-DEs, and these N-D Es, together with the pertinent empirical observations, form part of the chain of arguments used in testing the H-NE." If this requirement is not followed for any particular H-NE, than that explanation is not scientific. This is a serious problem for cladists, who generally claim that cladistic analysis must not be based on (presumably nomological, although this is not definitely stated) evolutionary theory (that is, fields a, c, d, and e of evolutionary theory outlined above). As cladistic analysis is clearly an H-NE, then it must be based on a pertinent N-DE, and if this N-DE is not nomological-deductive evolutionary theory, then there is the question: on what N-DE is cladistic analysis based? The argument that scientific order exists in nature by itself and in the absence of any N-DE is simply not valid.

Within evolutionary biology, descent with modification (field b of Darwin's theories), Haeckelian phylogeny, Darwinian or evolutionary classification, Hennigian cladification, historical biogeography and all analysis of the evolutionary history of any organic attribute or group (e.g., the evolution of the vertebrate limb, the evolution of flight in birds, the evolution of mammals from synapsid reptiles, etc.) are H-NEs. In geology, the sequence of sedimentary rocks, the pattern of movement of tectonic plates and the pattern of movement of the magnetic poles are H-NEs. These H-NEs are all explanations of singulars and not of universals. Hence a successful H-NE of the origin of flight in birds is of a singular event, and this H-NE will not serve as the explanation of the evolution of flight in bats even though both H-NEs are based on the same N-DEs such as aerodynamics.

Methodology in H-NEs must be based on the pertinent underlying N-DE. I have stressed this point in earlier papers on methodology in evolutionary classification (Bock, 1977, 1981, 1992) in which I endeavored to show that these methods are based on nomological-deductive evolutionary theory. The method advocated by cladists has to be examined closely to show whether they are based on appropriate N-DEs. I have stated earlier (Bock, 1978) that the basic cladistic method of out-group comparisons, as well as many other methods used by systematists in classification, is directly circular. Perhaps the problem is that cladistics actually start their analysis by first establishing groups of organisms and then use these hypothesized groups as the foundation for further analyses of apomorphy and plesiomorphy. If this is the case, then, cladists are silent about the methods used for establishing and testing theoretical statements about groups of organisms, leaving out a significant segment of their methodology. Clear statements about all of the methods used in any approach to systematic analysis are a major requirement that must still be detailed for most approaches to systematics.

Degree of Confidence of Historical-Narrative Explanations

Although H-NEs are theoretical scientific statements, they are basically tested inductively. A particular H-NE can never be proven, but it can be tested extensively so that one can have great confidence in its credibility. Hence one accepts and uses diverse H-NEs with very different degrees of confidence that depend on many factors, not only the methods used to test the particular H-NE. It is simply wishful thinking on the part of cladists to state that their modern methods are robust and will provide conclusions with a high degree of reliability. H-NEs vary greatly in the degree of confidence that one can have in their results.

Only a few H-NEs possess an exceedingly high degree of confidence. The monophyly of all known parrots (Psittaciformes) has such a high degree of confidence that very extensive contrary evidence must be marshaled to undermine it. The same is true for the conclusion that humans evolved from the anthropoid apes, and in particular from the chimpanzee-gorilla complex. Other H-NEs have varied in their degree of confidence over time. In the 1800s and early 1900s most ornithologists accepted the monophyly of the palaeognathous (i.e., flightless birds and the still flying tinomous) birds with strong confidence. Subsequently, most ornithologists accepted the independent origin of the several groups of these birds with equal confidence. After 1960, the monophyly of the palaeognathous birds was again accepted with high confidence (Bock, 1963). At the present time, the conclusion that the flightless ratites (see Bock and Bühler, 1990) are polyphyletic within the palaeognaths is accepted or rejected with varying degrees of confidence. Among the New World nine-primaried Oscines, there had never been any doubt about the monophyly of the species of Neotropical flower-piercers (*Diglossa*). However, a study of the corneous tongue and the bony palate of the skull demonstrated with considerable confidence that there are two distinct and unrelated groups of these birds with the very distinctively hooked, flower-piercer bill (Bock 1985).

Yet consideration of a large range of H-NEs of the relationships of organisms shows that most have a low degree of confidence at best. Considering birds, doubt still exists on the monophyly of many accepted orders such as the Piciformes, the Coraciiformes, Pelecaniformes, Falconiformes (Do the Cathartidae belong here or with the Ciconiiformes?) Cuculiiformes, Columbiformes (Do the Pteroclididae belong here or with the Charadriiformes?) and Galliformes (Do the Opisthocomidae belong here?). Furthermore, have birds evolved from dromaeosaurian dinosaurs or from an earlier basal group within the Archosauria? Among mammals, are the Glires a monophyletic group? Are the aquatic carnivores, the Pinnipeda, a monophyletic group or do they consist of two independently derived aquatic groups? The number of such examples could be increased well beyond the limits of anyone's patience to list or to read them.

What is needed is the establishment of a set of reasonable guidelines for the estimation of approximate degrees of confidence in H-NEs, even a simple listing of bad, poor, medium, good and excellent for these explanations. These methods depend largely on the empirical tests of hypotheses about taxonomic properties of features (homologies and directions of evolutionary change) and the establishment of a degree of confidence of the veracity of the conclusion.

Conclusions

A few conclusions can be offered. Most important is that before any analysis of explanations of evolutionary theory can be undertaken, one has to clarify the diverse areas within the overarching term *evolutionary theory.* Not all aspects of evolutionary theory are historical. Classifications, phylogenies, dendrograms, cladifications and all other explanations of the evolutionary history of groups of organisms and of particular attributes are H-NEs, and these explanations must be presented and tested in a very different way than the standard N-DEs in science. As for all H-NEs, evolutionary H-NEs must be presented realistically with a sensible estimate of the degree of confidence that one can have in the particular explanation. Otherwise the overall reputation of the entire field of H-NEs in biology will decrease sharply, as occurred at the end of the nineteenth century when there was a major rejection by biologists of the speculative conclusions being offered by evolutionary biologists. Investigations of historical aspects of biology are difficult enough without adding unreasonable claims about the methods of study, the nature of the explanations and the robustness of the conclusions (see Bock, 1992).

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