

# Telling the Tree: Narrative Representation and the Study of Evolutionary History

ROBERT J. O'HARA

*Department of Philosophy and The Zoological Museum  
University of Wisconsin – Madison  
Madison, Wisconsin 53706  
U.S.A.*

**ABSTRACT:** Accounts of the evolutionary past have as much in common with works of narrative history as they do with works of science. Awareness of the narrative character of evolutionary writing leads to the discovery of a host of fascinating and hitherto unrecognized problems in the representation of evolutionary history, problems associated with the writing of narrative. These problems include selective attention, narrative perspective, foregrounding and backgrounding, differential resolution, and the establishment of a canon of important events. The narrative aspects of evolutionary writing, however, which promote linearity and cohesiveness in conventional stories, conflict with the underlying chronicle of evolution, which is not linear, but branched, and which does not cohere, but diverges. The impulse to narrate is so great, however, and is so strongly reinforced by traditional schemes of taxonomic attention, that natural historians have more often abandoned the diverging tree than they have abandoned the narrative mode of representation. If we are to understand the true nature of the evolutionary past then we must adopt "tree thinking", and develop new and creative ways, both narrative and non-narrative, of telling the history of life.

**KEY WORDS:** Cladistics, classification, evolutionary history, narrative, natural history, natural system, philosophy of history, philosophy of science, phylogeny, progress, systematics, tree thinking, tree topology.

## INTRODUCTION

It is absurd to talk of one animal being higher than another. We consider those, when the intellectual faculties (cerebral structure) most developed, as highest. A bee doubtless would when the instincts were.

Darwin, in Barrett (1960, p. 259)

Charles Darwin's achievement has appeared in many guises to many different people. For some it was the paramount intellectual event of the nineteenth century, and perhaps of any century. For others it was, and continues to be, the work of the Devil himself. However one may view the Darwinian achievement in its totality, one of the things it is certainly is a part of a much larger move-

ment in Western thought, a movement which has, over the last few centuries, led scholars to view the world from an increasingly *historical* perspective. From the cosmology of Immanuel Kant, wherein “Millions and whole myriads of millions of centuries will flow on, during which always new Worlds and systems of Worlds will be formed” (Toulmin and Goodfield 1965, p. 132); to the geology of James Hutton, who saw for the earth “no vestige of a beginning, – no prospect of an end” (Greene 1961, p. 84); to Buffon’s characterization of species as historical individuals rather than logical universals (Sloan 1987); to even William Jones’s proposition that Latin, Greek, and Sanskrit all share a common genetic ancestor (Mallory 1989, p. 12), one of the central themes in the story of scholarship over the last four hundred years has been the growing realization that time extends backward almost farther than we can imagine, and that the world has not always been as it is today. “In the whole history of thought no transformation in men’s attitude to Nature – in their ‘common sense’ – has been more profound than the change in perspective brought about by the discovery of the past” (Toulmin and Goodfield 1965, p. 17).

Those of us who work in the historical sciences of systematics and evolutionary biology often think of ourselves as being more aware of the historicity of nature – more aware of the natural past – than are our colleagues in the physical and functional sciences. And yet science, like nature, is itself “a complex and heterogeneous *historical process*” and it “contains vague and incoherent anticipations of future ideologies side by side with highly sophisticated theoretical systems and ancient and petrified forms of thought” (Feyerabend 1988, p. 111). It is the thesis of this paper, as it was of my earlier essay on this same general topic (O’Hara 1988a), that the process of “historicization”, the process whereby investigators become fully aware of the historical character of their subject, has not yet been completed even within the so-called historical sciences of systematics and evolutionary biology. This process can be advanced, so I believe, by examining systematic methods and systematic difficulties not in the context of the philosophy of science, as has traditionally been done, but rather by examining them in the context of the philosophy of history. It is that examination that I continue here. The reason that the philosophy of history sheds particular light on systematics is that the object of systematics in the Darwinian world is the reconstruction of evolutionary history (O’Hara 1988a, 1991; de Queiroz 1988). The equation of systematics with classification is one of the ancient and petrified notions we have inherited from the pre-evolutionary period, one that we ought now to abandon. The problems of systematics now and in the future are not the problems of classification, they are the problems of historical reconstruction and historical representation: the reconstruction and representation of the evolutionary past.

In the course of my arguments I wish it to be clear that in comparing many of the activities of systematists and evolutionary biologists to history rather than to science I do not intend to diminish those activities. Far from making systematics and evolution appear to be somehow less than Science with a capital *S*, I hope instead to contribute to the building of a new Natural History, with a capital *H* –

a field whose domain will be nothing more nor less than the study of the *history* of nature. Those who view history as in some way a simpler discipline than science have an impoverished view of history. The activities of natural historians should be seen as no less challenging than those of natural scientists, and when they are viewed in the context of other historical disciplines these activities will suffer from a good deal less confusion of method and of object.

It is difficult to enter into any theoretical discussion of evolutionary history without confronting a notion which has long been controversial, namely, evolutionary progress. The notion of evolutionary progress has a vast literature; the recent volume edited by Nitecki (1988) provides an entry into that literature, and it reviews excellently many aspects of the progress question. Even more recently, Gould (1989) has addressed the question of historical inevitability in evolution, an idea closely related to the idea of progress. As Richards has pointed out (1987, p. 17), a sense of inevitability can easily arise in both historical and evolutionary narrative because the endpoint is known, and because all that precedes the end point can be viewed teleologically. Historians have often remarked on how inevitable events seem when viewed from a distance, and how accidental when viewed up close (see for example Bailyn 1967). While much of what I have to say in this paper bears on the questions of historical inevitability and evolutionary progress, I approach these issues from a new perspective. I believe that before we can usefully discuss the occurrence of particular historical phenomena (such as evolutionary progress), we must first address the general problems associated with all forms of historical representation. Therefore, rather than arguing for or against the existence of evolutionary progress "empirically", or examining the sociocultural context of progressivist views, I examine here the linguistic, literary, and classificatory apparatus that allows progressivist discourses to be created in the first place. Although I do not discuss either progress or historical inevitability explicitly, I hope that the discussion I do present will illuminate aspects of these problems that have hitherto been obscure.

#### NARRATIVE THEORY AND THE PHILOSOPHY OF HISTORY

As in my previous paper (O'Hara 1988a), when I speak here of the "philosophy of history" I am referring to what may be called the critical or analytical philosophy of history, the discipline which studies not the past itself, but rather the way in which historians think and write about the past. The analytical philosophy of history attracted attention in the 1950s, and during its early years it operated largely in reaction to the work of philosophers of science who were attempting to bring history under the philosophical umbrella they had opened over the physical sciences. The earliest concerns of analytical philosophers of history paralleled those of the philosophers of science of the time, and included the structure of historical explanation, the ways in which historical explanation differs from scientific explanation, the function of general laws in historical

writing, and so on. Some of these topics, as they relate to the structure of evolutionary biology, I have touched upon previously.

As the analytical philosophy of history matured during the 1960s it began to generate issues and problems of its own, and it became more of a self-sustaining discipline, albeit a small one, and less simply a reaction to the philosophy of science. One of the most challenging issues it came to concern itself with, owing largely to the work of Arthur Danto (1985), William Dray (1989), William Gallie (1964), Louis Mink (1987), Morton White (1965), and others, was the nature of historical narrative. And as the study of historical narrative developed, some scholars, most notably Hayden White (1973, 1987), began to blend the insights of analytical philosophers of history with those of literary theorists, who have long been interested in narrative writing.<sup>1</sup> Literary narratives may differ from historical narratives in giving accounts of fictional events rather than real events, but literary and historical narratives both partake of the fundamental characteristic of narrative discourse, which is to have not only a *tale* – an underlying sequence of events with a beginning and an ending – but also a *teller*. And though their interests differ in certain respects, students of literary and historical narratives both have as one of their central concerns *the role of the teller in the deployment of the tale*.

In the sections that follow I will first review some of what has been said about the role of the teller in literary and historical narratives, contrasting this with the role of the investigator in science as it is conventionally understood. I will then look at traditional accounts of evolutionary history to see how they exemplify the historical rather than the scientific mode of understanding. Finally, I will consider how the writing of evolutionary history could be improved in both narrative and non-narrative ways.<sup>2</sup>

#### THE UNEQUAL EYE

It is the traditional ideal of science to be observer-independent. While scientists acknowledge that their individual personalities and backgrounds may influence their choice of a research topic or the particular manner in which their research is conducted, all scientists hope that the conclusions they draw from their research will be able to stand alone, independent of the individuals who drew them. There are certain areas of science, such as relativistic and quantum physics, where the observer is acknowledged to have an important influence on the results, but in these fields it is not any particular observer that matters, but rather any observer at all: an American physicist and a German physicist will both experience the same phenomena when they are travelling near the speed of light. In the words of Dray (1989, p. 55), “scientific conclusions do not – or at any rate, ought not to – depend on the feelings, outlooks, or backgrounds of those who reach them”. This notion of science as an observer-independent form of inquiry has very deep roots, and Toulmin has argued (1988, 1990) that the sources of modern science are to be found in attempts to transcend the tumultuous observer-dependent politics of early modern Europe – in attempts to

establish an “empire of reason” upon foundations which lie outside the subjective particularities of human experience.

Historians, in contrast to scientists, have always been more or less aware that their conclusions have an observer-dependent aspect to them. While certain historians have from time to time wished for “scientific” objectivity – wished to tell the past “as it really was” – most historians have acknowledged that the problem of *point of view* is something that is built into historical scholarship, and that it cannot be avoided. History, in contrast to science, is necessarily a perspectival form of inquiry (Dray 1989, p. 54).

What precisely does this observation entail, that history is a perspectival form of inquiry? To begin to answer that question let us again make the conceptual distinction between chronicle and history proper which is common in studies of narrative history (Danto 1985; O’Hara 1988a). A chronicle is a series of statements about some thing at different times in its past, arranged in chronological order, but not accompanied by any statements of explanation or interpretation: A was x at  $t_1$ , and y at  $t_2$ , and z at  $t_3$ . Historical statements, in contrast to chronicle statements, do contain explanations of events, interpretations of their significance, and so on.

There are of course problems with the chronicle/history distinction, and if it is pushed to its limits it can break down. It may be argued that all language is interpretive to some degree, and that it is impossible simply to describe things and events without in some measure interpreting them as well. This may be true in an absolute sense, but for my purposes here I do not believe it is important. For my purposes the distinction between chronicle statements such as “Columbus sailed west from Europe and made a landfall on such-and-such a day in 1492” and interpretive historical statements such as “Columbus opened the New World in 1492” will remain clear. If we accept this distinction between chronicle and history, we may see that the chronicle is in a certain sense the “scientific” part of historical research, in that the elements of a chronicle, *taken individually*, are assumed to be agreed upon by all investigators; the elements of a chronicle are, taken individually, not observer-dependent.

When historians are engaged in primary research on specific problems they will ordinarily attempt to assemble as full a chronicle as possible, and will always be searching for more documents and more artifacts to flesh out the actual sequence of events pertaining to their subjects. But whenever historians step back from primary research, to the level of review articles, popular essays, or textbooks, the rich detail they could comprehend all at once in the narrow case now becomes overwhelming. The writers of such works must always select from, abridge, and simplify their research chronicles in order to be comprehensible: they must give attention to certain events to the exclusion of others. We may ever dream of having the ability Alexander Pope attributed to the Deity, who

Sees with equal eye, as God of all,  
A hero perish, or a sparrow fall,  
Atoms, or systems, into ruin hurl’d,  
And now a bubble burst, and now a world.

But this ability will ever elude us, because to see all things with equal eye is not within our power: humans, and especially human narrators, always look upon the world with an unequal eye.

The differential attention given by historians to different events is paralleled in the case of fictional narratives. Although there is no factual chronicle underlying a fictional narrative, there is nevertheless an underlying sequence of events which may be abstracted from such a narrative, and these events are not all attended to equally over the course of a story. Further, it is possible in the case of fictional narratives to imagine some more inclusive universe of events from which those that are actually mentioned in a story have been drawn. In describing the structure of stories literary theorists often speak of a narrative landscape, and this metaphor is a good one: from the point of view of a narrator one may envision a landscape of things and events, some in the foreground, looming large and receiving much attention, others in the background, farther away and less distinct. Creative writers have even been known to manipulate the narrative landscapes of other authors' works for artistic effect. Those familiar with the Anglo-Saxon epic of *Beowulf*, in which Beowulf the hero slays Grendel the monster, may not be aware that there is a rather more recent work called *Grendel* (Gardner 1971) which retells the story of Beowulf from the point of view of the monster. The events may be the same, but the entire scheme of attention – the entire narrative foreground and narrative background – are different. It's like retelling the *Iliad* from the perspective of Helen of Troy. The first three volumes of Lawrence Durrell's *Alexandria Quartet* (Durrell 1957, 1958, 1959) provide another illustration: each of these novels is set at the same time and in the same location, and each is interwoven with the other two, but each is written from a different point of view.

The authors of fictional narratives have complete control over the narrative landscapes of their works, of course, and can pull events into the foreground, push events into the background, and give attention to whatever they choose. But historians do not have the freedom that novelists or poets have to create fictional worlds: historians aspire to write narratives that are not only cohesive, but also truthful. If all of the events in an historian's research chronicle are true, however, we may fairly enquire after the grounds on which historians select events from their detailed research chronicles for inclusion in more general narratives; we may enquire after the grounds on which historians build up their own narrative landscapes.

A number of the criteria of attention used by historians have been identified and named. These include: moralism, attending to things and events which illustrate proper or improper conduct on the part of persons and institutions; abnormalism, attending to things and events which are unusual or bizarre; estheticism, attending to things and events which are pleasing or beautiful; essentialism, attending to things and events which embody the essence of a period or a nation; and so on (M. White 1965). In practice an historian may use a combination of all of these criteria when selecting events for inclusion in a narrative.

More important than the recognition of any of these particular criteria, however, is a general observation that can be made concerning the application of all such criteria. This observation is that an historian's determination of what things are moral, or abnormal, or esthetic, or essential, may be based upon judgements which to a considerable degree lie outside the content of the research itself. If one is to approve of a particular historical account – to judge that it is a good history – one must also approve of, or at least accept, the *metahistorical* standpoint of the historian: the standpoint from which the criteria of selection were applied. Many examples could be used to illustrate the importance and influence of metahistorical standpoints, among them the classic “Whig interpretation of history” described by Herbert Butterfield (1931): Protestant and Catholic historians of Britain may see the same events in British history in very different ways, and produce incompatible narrative histories as a result. Other examples could be found in the contrasting accounts of many historical episodes offered by Marxist and non-Marxist historians. The metahistorical standpoint of an historian is the point from which the narrative landscape radiates; it is the point from which the narrative foreground and narrative background are identified.

The ability to make general designations such as “Whig history” or “Marxist history” points to another important characteristic of historical narratives, namely that the individuals who produce them are members of communities. Historical narrators, being themselves products of history, are not distributed independently and randomly over the earth, but instead are clumped: clumped by language, clumped by nationality or religion or politics, clumped by specialization or period, and so on. And whether they be Protestants or Marxists or Americans or New Zealanders, clumps of narrators, standing side-by-side in the narrative landscape, often share common schemes of narrative attention – they often recognize the same narrative foregrounds and backgrounds. The collection of things and events commonly attended to by such a community of narrators may be thought of as a canon, and a canon of historical events, or a canonical scheme of attention, once established, may be perpetuated to some degree by social factors, and may develop a certain social inertia. Students learn what is important from their professors, and in turn teach those same things to their students; books that treat canonical subjects stay in print, books and papers on extracanonical subjects go out of print, are read less often, are bought by fewer libraries, and so on. This is not some sort of conspiratorial process; it is simply an inevitable feature of any process that involves tradition, as the educational process surely does, and it will continue as long as people learn from their predecessors. Canonical schemes of attention are by no means unalterably fixed; many of the “alternative” movements in history (women's history, black history, and so on) are attempting to restructure or expand traditional canons of attention, and to make historians see past events from new and different metahistorical standpoints.

The perspectival character of narrative history has led some historical scholars to despair of ever putting their discipline on a firm foundation. They believe that

narrative theory reveals historical scholarship to be (as it perhaps has always been) nothing more than an instrument of political or social ideology. "Many modern historians", writes Hayden White in characterizing this view,

hold that narrative discourse, far from being a neutral medium for the representation of historical events and processes, is the very stuff of a mythic view of reality, a conceptual or pseudoconceptual "content" which, when used to represent real events, endows them with an illusory coherence and charges them with the kinds of meanings more characteristic of oneiric than of waking thought. (H. White 1987, p. ix)

Other writers have opposed this extreme view, arguing the more moderate position that "there must be some reality which perspectival appearances are appearances of" (Dray 1989, p. 70). These authors suggest that the task of the good historian (or of the reader faced with several bad historians) is to create neither an "objective" account, for there may be no such thing, nor a perspectival account, because the account from another perspective may be equally valid, but rather to create an *inter-perspectival* account, by which we are enabled to see how the past appears from many different points of view. In an inter-perspectival account

the synthesis which constitutes the achievement of objective history is the system of perspectives themselves. Ernest Nagel formulates this conception as follows: "students operating within different social perspectives can obtain objectivity in a 'roundabout fashion' by construing their inevitable differences in the light of the differences in the structure of their perspectives". [Nagel 1959, p. 213] What matters, he says, is that there be a "translation formula" which connects what is said from the various perspectives in a necessary way.... Mention of "translation formulas" may evoke only splendid visions of the hardware one may hope to find in history departments of the future: point of view converting machines, perhaps, which, when properly programmed with appropriate metaphysical and moral assumptions, will gobble up a volume of Hume and disgorge it Macaulayesque. But the general idea of this "relational" type of objectivity isn't hard to grasp. (Dray 1989, pp. 71-72)

Under an inter-perspectival view, says Dray, the desire for objectivity can be legitimately retained if we regard the things which historians seek agreement about to be not the past itself, but rather the way the past appears from different perspectives.

#### THE WHIG INTERPRETATION OF EVOLUTION

If we turn now to the study of evolutionary history, while keeping in mind the foregoing review of narrative theory, we discover many parallels. Primary research into the history of nature – that is to say, primary research in systematics, the study of the evolutionary chronicle – is like primary research in history proper in that original researchers in both fields ordinarily work on very narrow topics and they endeavor to establish as many details and the occurrence of as many events as possible. In systematic terms we would say that researchers ordinarily specialize in the study of particular clades, and that in estimating the



phylogeny of those clades they try to use as many characters as they can, characters being differences from which we infer the events of evolutionary history. Like research papers in academic history, the products of primary systematic research are usually of interest only to a small number of specialists.

The research chronicle of the systematist differs in an important respect from that of the historian, however, in that the chronicle of evolutionary history is strongly branched. Chronicles in human history need not be conceived of as rigidly linear, to be sure, and a skillful historian may develop a variety of more or less independent story lines within any one narrative. The flow of events and influences in human history is perhaps analogous to the irregular flow of genetic information through the populations of an individual species. Generally speaking, however, the evolutionary chronicle is fundamentally branching in character, fundamentally tree-like, in a way that historical chronicles, and even linguistic chronicles (because of the amount of horizontal transmission they contain) are not. The peculiar branching character of the evolutionary chronicle will be significant when we consider in a moment the particular devices which have been used in the construction of evolutionary narratives.

When natural historians step back from the details of their research chronicles, back to textbooks, popular essays, museum exhibits, and the like – works in which they endeavor to give abbreviated views of the whole of evolutionary history – they are once again in a situation similar to that faced by the authors of abbreviated human histories. To produce abbreviated works, natural historians, like human historians, must select, abridge, and simplify the results of primary research. It is not possible to see all the events of evolutionary history with equal eye any more than it is possible to thus see the events of human history, indeed it may be more difficult in the case of evolutionary history because of the richness of living diversity. If natural historians must necessarily select, abridge, and simplify in the course of their writing then the question immediately arises whether the selections made by natural historians are made from some particular metahistorical standpoint, as are the selections of human historians. Is there, for example, an interpretation of the evolutionary past which is analogous to the “Whig” interpretation of history?

I believe that there is a very serious problem of metahistorical standpoint in narrative accounts of the evolutionary past. This problem is not, however, a problem of Protestant versus Catholic natural historians, or of European versus American versus African natural historians, but rather of *human* natural historians versus ... no one. All general accounts of the history of life are accounts which have been written by humans from the human standpoint, and this has caused us to possess a deeply colored view of evolutionary history. Why are evolutionary biologists perhaps less aware of this problem than are historians, who have long been conscious of the problem of point of view? The reason that the problem of point of view arises in history proper is that there exist histories which are written from different points of view and which conflict with one another (Dray 1989, p. 55). But if one were to imagine that historians existed only among, say, the British upper class, and in no other communities

anywhere else in the world, then it would be easy to see how all histories of the world might bear the stamp of the British upper class. This is precisely the sort of situation which exists in natural history: all historians of evolution are members of one small community (humans), and all evolutionary histories bear the stamp of the human perspective. Our common membership in this community blinds us to the effect our perspective has had on our representations of the past: "Membership in a group or school may ... reduce the pressure upon an historian to eradicate prejudices which members of that group or school may have in common, and it may also make it harder for the historian himself to recognize them (Dray 1989, p. 55). A Protestant British historian may be held in check by a Catholic British historian, but there are no coelacanths, no bird's nest fungi, no vestimentiferan worms writing evolutionary history.

How in particular has the human standpoint influenced our representations of the evolutionary past? I will outline here four narrative devices through which this influence has been exerted, and give examples to illustrate each of them. (For other examples see O'Hara 1988b, 1991.) I call these *narrative* devices for two reasons: first, they define "channels" along which the course of a story proceeds, usually by specifying a beginning point and an ending point; and second, each of these devices *could* be applied from any point in the evolutionary tree; in practice, however, all have generally been applied only from the human position. It is this last feature that makes these devices metahistorical, and analogous to the criteria of historical attention (abnormalism, estheticism, etc.) discussed above. These four devices are: (1) the graphical and textual sequencing of contemporary taxa; (2) the pruning of "side branches" to create a "main line" of evolution; (3) the naming of paraphyletic taxa which, when named, can function as stages in a narrative sequence; and (4) the subtle but very important device of differential resolution of different parts of the evolutionary tree. I shall pay particular attention to this last device, differential resolution, because it is perhaps the least obvious of the four. I do not claim that this taxonomy of narrative devices is a final one; in most cases these devices act in combination with one another, and it may be possible to classify them in other useful ways.

The first narrative device, the sequencing of contemporary taxa, can be seen graphically in Figure 1, an evolutionary tree of the primates taken from Romer's *The Vertebrate Story* (fourth edition, 1959), an extremely popular textbook of vertebrate evolution that was widely used during the middle years of this century. The tree in this figure is branching, but the branching is far less important as a conveyor of information than is the sequence of taxa reading from lower left to upper right, all of which (with the exception of the hypothetical ancestor at the bottom) are living today. This curving sequence of contemporary taxa is the narrative axis of the diagram, the axis along which the evolutionary story is meant to be read. The text accompanying this figure sequences these contemporary taxa with the same effect; it is a fine example of the rhetorical scheme of climax:

The living primates, for our purposes, may be divided primarily into three groups: (1) the lemurs, or prosimians, typically small four-footed forms of rather squirrel-like appearance, found today in the Old World tropics and present in the Eocene in Eurasia and North America; (2) *Tarsius*, a curious small, hopping ratlike creature from the East Indies and its fossil relatives, occupying an intermediate position between lemurs and higher primates; (3) the anthropoids, comprising the South American monkeys, the more advanced monkeys of the Old World, the great man-like apes, and man. (Romer 1959, pp. 309–310)

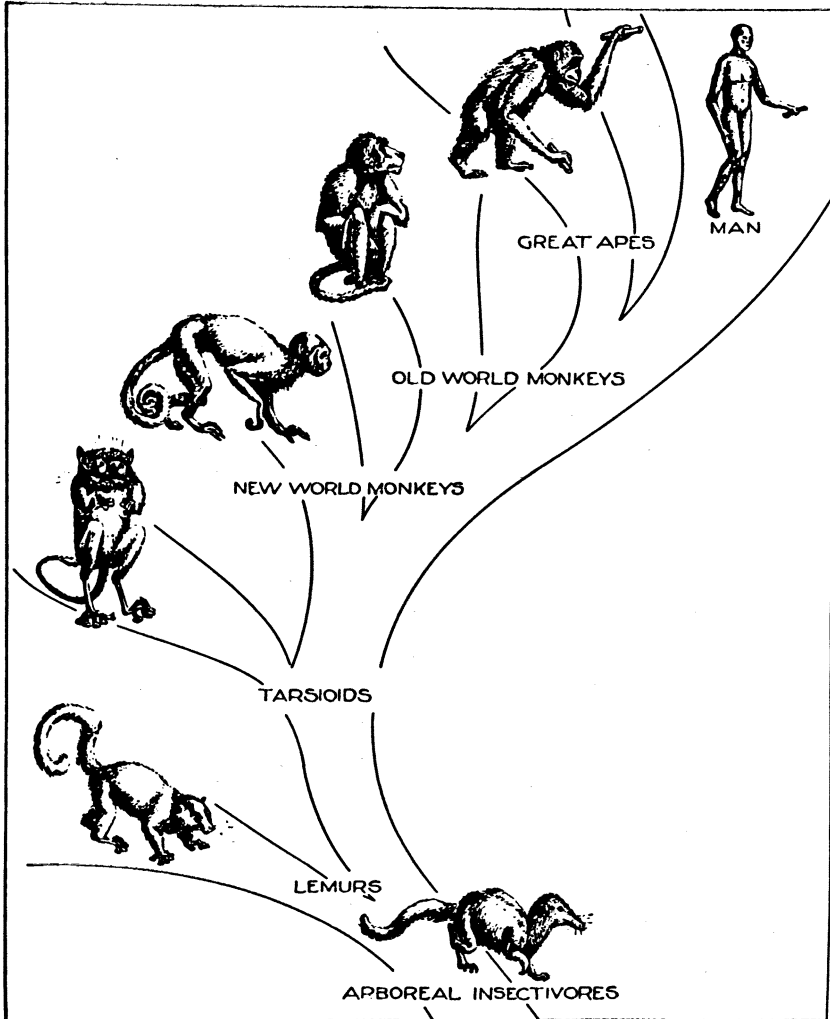


Fig. 1. "A simplified family tree of the primates" from Romer (1959, p. 310). The narrative axis of the diagram passes from lower left to upper right through a series of contemporary taxa. (Reprinted courtesy of the University of Chicago.)

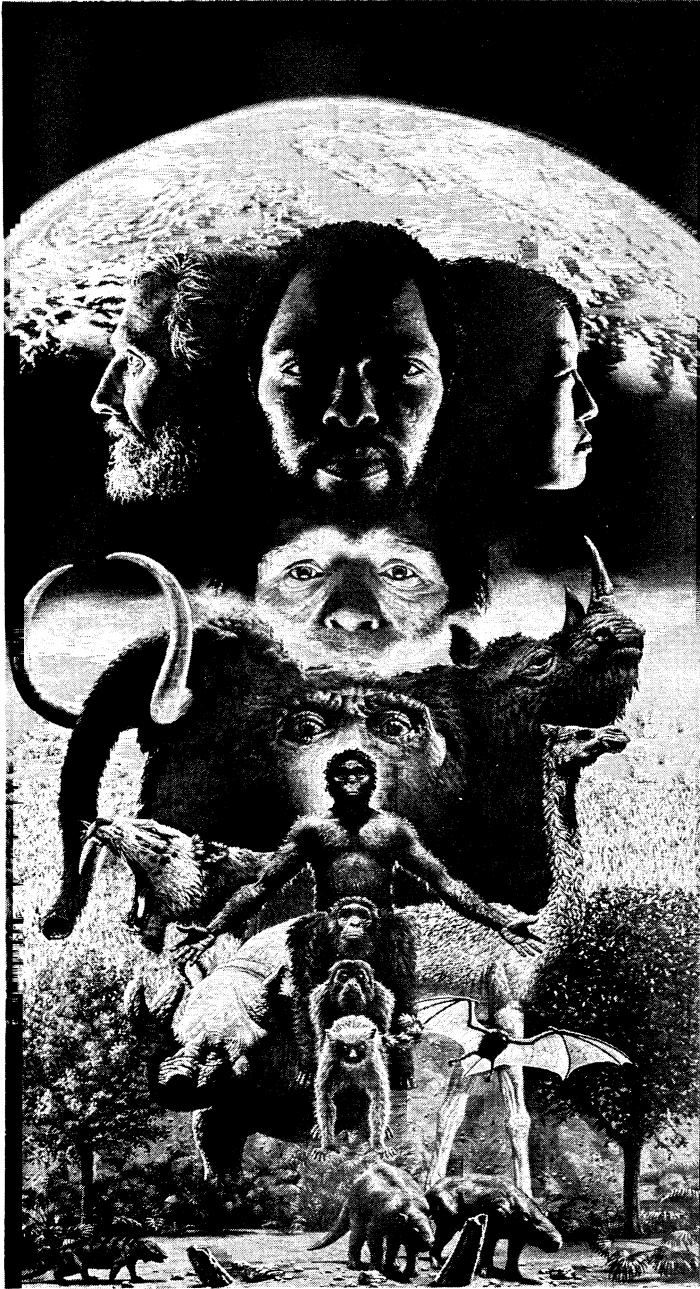


Fig. 2. "The Face of Man", a painting by John Gurche, from the "Tower of Time" exhibit at the National Museum of Natural History, Smithsonian Institution, Washington, D.C. The color original is reproduced in Lewin (1982) and Reader (1986). (Reprinted courtesy of the Smithsonian Institution.)

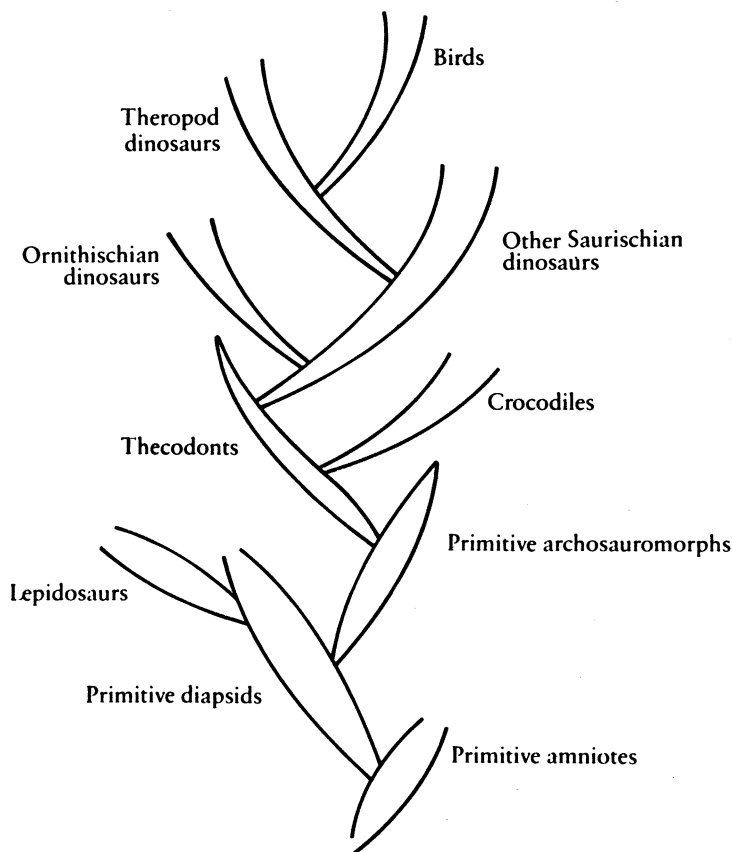


Fig. 3. "Succession of paraphyletic groups leading from primitive amniotes to birds".  
From Carroll (1988, p. 13). (Reprinted courtesy of W. H. Freeman and Company.)

The frequent use in *The Vertebrate Story* of expressions like "from fish to men" and "toward land life" contribute still further to the narrativity of the work by specifying as they do both the beginning and the end of a sequence. The same effect is created when *taxa* are referred to as primitive or derived, primitive or advanced, lower or higher (de Queiroz 1988, p. 252), a practice which is still widespread (American Ornithologists' Union 1983, p. xvi ff.).

The second narrative device, the pruning of side branches to create a "main line" of evolution, is illustrated in Figure 2, a striking painting by the artist John Gurche entitled "The Face of Man" (reproduced in Lewin 1982 and Reader 1986). This painting clearly sequences a number of *taxa*, but the sequencing in this case is legitimate because the *taxa* are represented as being species directly ancestral to humans. However, the existence of descendants of these species other than those on the direct human line – such as all the other living primates –

is ignored, and this is what is meant by pruning side branches: only one line (out of a great many) is traced through the evolutionary tree. If this painting is taken in isolation the pruning of side branches may be defended on the grounds that the illustration is only meant to convey an idea of *human* evolution. The pruning of side branches may not be defended, however, when the greater context of the illustration is considered. This painting is not only sold as a poster in the National Museum's gift shop, it also caps a tall mural in the Museum's public exhibit halls called the "Tower of Time", an exhibit which is meant to illustrate the whole history of life (this mural is reproduced as a folding chart in Lewin 1982). From a spherical colony of single-celled organisms at the bottom to the three human faces (arranged to tell a biogeographic story) at the top, the "Tower of Time" presents a view of evolutionary history – indeed, of "time" itself – which leads directly and exclusively to *Homo sapiens*.

The visual sequencing of contemporary taxa as well as the third device of the naming of paraphyletic groups can be clearly seen in Figure 3, taken from Carroll's recent textbook of vertebrate paleontology (1988). This illustration is intended to show the "succession of paraphyletic groups leading from primitive amniotes to birds". Crocodiles and lepidosaurs, however, have living representatives, and so are contemporary with birds at the top of the diagram; on what basis, then, are these taxa illustrated as being *below* birds in their entirety? (That is to say, what does the vertical axis of the diagram represent?) Further, the recognition and naming of the paraphyletic groups in the diagram (crocodiles and lepidosaurs are not considered to be paraphyletic) allows the author to show a "succession" *from* a beginning *to* an ending which he would not have been able to show without the recognition of such taxa.

It may be objected at this point that the examples presented here are taken either from popular works or from non-cladistic works, and that they are therefore irrelevant to many contemporary systematists. There are two responses to this objection. First, the boundary between popular and technical works is not sharp. The narrative phenomena I am examining are inherent in the process of simplification and abridgement, wherever that process may take place; the process is most conspicuous in heavily abridged popular works, but it occurs (albeit to a lesser degree) in technical works as well. Furthermore, it is from abridged and popular works that most people learn the principles of evolution. If evolutionary biologists are concerned that not only students but also their colleagues in other disciplines learn these principles correctly – and I believe they should be so concerned – then they need to give attention to the processes by which their research results are simplified. Second, cladistic systematics frees one from the pitfalls described here, does it not? I asserted above, for example, that it was the naming of paraphyletic groups in Figure 3 that allowed the taxa in that diagram to be sequenced, and that without the recognition of those groups the sequencing would have been impossible. Paraphyletic taxa do make sequencing easier, but they are not essential to sequencing, as can be seen from an examination of Figure 4, a cladistic diagram published in a recent Nobel symposium entitled "The Hierarchy of Life" (Fernholm et al. 1989). This

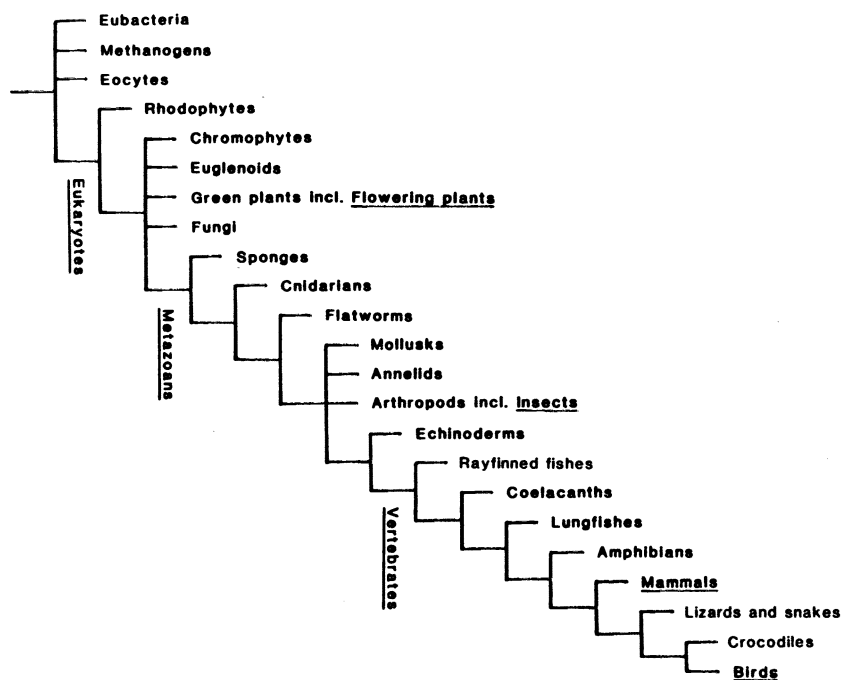


Fig. 4. "The hierarchy of life. Attempt at showing relationships among selected major groups of organisms". Compiled by K. Bremer, from Fernholm et al. (1989, p. v). (Reprinted courtesy of Elsevier Science Publishers and B. Fernholm.)

cladogram employs a degree of visual sequencing almost identical to that seen in Romer's primate tree (Figure 1): in reading from upper left to lower right we follow the narrative axis of the diagram through a series of contemporary taxa. The representation of sister clades as having unequal branch lengths (as in Figure 1) enhances the linearity of the diagram. But the narrative device that is illustrated most clearly by this diagram is differential resolution, a device that appears in both popular and technical works, and which I shall consider next.

To understand the notion of differential resolution, and its complement tree simplification, consider the hypothetical phylogeny shown in Figure 5a. Let us suppose that this diagram illustrates what I have called a research chronicle: the most thorough and detailed representation of the history of the 63 clades shown that is currently available. Let us further suppose that we wish to simplify this diagram for inclusion in a textbook, or a review article, or for use in a lecture. One way to effect this simplification would be to collapse the tree symmetrically, until only taxa 1–15 were shown (Figure 5b). But this is in fact only one of many ways in which the original tree may be simplified. A symmetrical binary tree – one like Figure 5a – having 4 ( $2^2$ ) terminal taxa may be

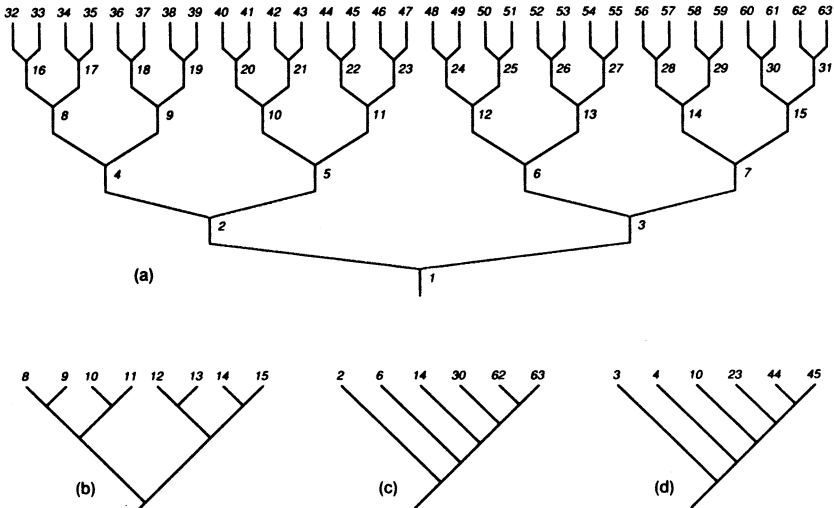


Fig. 5. The problem of differential resolution, illustrated by a fully resolved tree made up of 63 clades (a), and three of the possible simplifications of that tree (b-d). Of the thousands of possible simplifications of the tree shown in (a), 16 are perfectly comb-like.

simplified in 4 ways (including being collapsed into a single branch); one with 8 ( $2^3$ ) terminal taxa may be simplified in 25 ways; one with 16 ( $2^4$ ) terminal taxa may be simplified 676 ways, and so on. Of the total number of possible simplifications of a binary tree with  $2^n$  terminal taxa,  $n/2$  will be perfectly comb-like (as are Figures 5c and 5d). The number of possible simplifications of a tree that is not perfectly symmetrical and binary will be fewer than that for a symmetrical binary tree, but it may still be very large.

Now if the simplification of research results were always done against an historical background of total ignorance of the taxa under study, then we might choose the symmetrical simplification shown in Figure 5b and be content. But original research and its subsequent simplification are hardly ever done against a background of total ignorance. For almost any taxon one may choose to study there will already be a collection of preexisting names and subtaxa that have been defined and recognized by previous workers. These preexisting names and taxa will ordinarily correspond to only a fraction of the total number of clades identified in a new cladistic study, however, not only because names that apply to paraphyletic taxa will have to be dropped, but also because cladistic studies usually yield greater levels of resolution than did earlier non-cladistic studies. The important point to recognize is that in simplifying or summarizing the results of a new cladistic study, authors will be more likely to simplify their results in such a way as to align them with the preexisting nomenclature as much as possible. If one had a complete phylogeny of the 9000 species of birds, for example – a phylogeny made up of many thousands of clades – one would find



that some of those clades, though not all, would have names already in existence for them. If one wished to then simplify that complete phylogeny for educational or review purposes down to, say, 50 clades, it would be most practically useful if the simplification brought the tree into alignment with the traditionally recognized orders and families of birds, and did not compromise the names of those taxa, since their names are widely known and are referred to throughout the literature. If it turned out that, for example, the Passeriformes and the Psittaciformes were sister clades, then every effort would be made to include both of these as separate branches in the simplification rather than to join them into a single branch, because no name currently exists for a taxon consisting of Passeriformes+Psittaciformes. A new name could be created of course, but such an action would to a considerable extent defeat the purpose of the summary view, which is to allow readers to fit what they already may know into a new and presumably more up-to-date context. A similar case of the influence of preexisting nomenclature has been discussed by Raikow (1986, 1988).

In the study of any large clade, the problem of differential resolution is introduced not only after the study is completed and its results are being summarized; the problem is introduced before the study even begins. Any cladistic analysis that uses genera or families or orders as terminal taxa has built into it the particular pattern of resolution that those terminal taxa embody. Many such patterns of resolution will derive from the traditional evolutionary systematics of the late 19th and early 20th centuries, much of which is in turn derived from pre-evolutionary systematics, from the Great Chain of Being (Lovejoy 1936; Figure 6), and from “natural interpretations” (Feyerabend 1988), the vernacular terminology and categories of thought in European culture. Atran (1990) has begun an investigation of these categories from the perspectives of cultural and historical anthropology, and his work could almost certainly be extended with psychological studies in the present. A model for such studies may be found in the research that has been done on geographical perception and “mental maps” (Downs and Stea 1977; Haynes 1980; Gould and White 1986). Systematic diagrams, like Figure 4, that exhibit traditional patterns of resolution are directly analogous to observer-centered geographical maps in which the scale varies with the distance from the observer. The well-known maps that present “A Bostonian’s View of the World” or “A New Yorker’s View of the World” (Gould and White 1986, pp. 20–21) are maps of this sort, and although they strike us as humorous, the type of distortion that they exhibit is a relatively common feature of “naive” geographical perception.<sup>3</sup>

Considerations of differential resolution and tree simplification are extremely important for any attempts at using tree structure to say something about the evolutionary process – about patterns of speciation, for example. Shao and Sokal (1990) have reviewed the literature on this topic in their recent discussion of tree balance. The balance of a tree refers to the extent to which its branching is symmetrical: Figures 5a and 5b show perfectly balanced trees, while Figures 5c and 5d show perfectly imbalanced trees. Statistics of tree balance are of uncertain value, however, when they are calculated on trees that may be

*IDE'E D'UNE ECHELLE  
DES ETRES NATURELS.*

L'HOMME.
Orang-Outang.
Singe.
<b>QUADRUPEDES.</b>
Ecureuil volant.
Chauvefouris.
Autruche.
<b>OISEAUX.</b>
Oiseaux aquatiques.
Oiseaux amphibies.
Poisons volans.
<b>POISSONS.</b>
Poisons rampans.
Anguilles.
Serpens d'eau.
<b>SERPENS.</b>
Limaces.
Limaçons.
<b>COQUILLAGES.</b>
Vers à tuyau.
Teignes.
<b>INSECTES.</b>
Gallinfectes.
Tenia, ou Solitaire.
Polypes.
Orties de Mer.
Sensitive.
<b>PLANTES.</b>
Lychens.
Mouffures.
Champignons, Agarics.
Truffes.
Coraux & Coralloïdes.
Lithophytes.
Amianthe.
Talcs, Gyps, Sélénites.
Ardoises.
<b>PIERRES.</b>
Pierres figurées.
Crytallisations.
<b>SELS.</b>
Vitriols.
<b>METAUX.</b>
<b>DEMI-METAUX.</b>
<b>SOUFRES.</b>
Bitumes.
<b>TERRES.</b>
Terre pure.
<b>EAU.</b>
<b>AIR.</b>
<b>FEU.</b>
Matières plus subtiles.

Fig. 6. A representation of the Great Chain of Being, from Bonnet (1745). The original is a single folding column; it is shown here in two parts for reasons of space. The Chain of Being is the source of much of the narrativity in our representations of evolutionary history.

narratively simplified versions of fully resolved trees (as, for example, in Savage 1983). Figure 5b and Figures 5c and 5d exhibit the extremes of balance and imbalance, and yet all are just different simplifications of the same phylogeny (Figure 5a). It is even possible to take a strongly imbalanced tree and balance it by selective simplification. Conclusions about evolutionary processes that are based on the structure of trees that have been, by selective simplification, brought into alignment with preexisting nomenclature probably say less about evolution than they do about the narrative character of the preexisting nomenclature.

The problems of differential resolution and tree simplification are problems of attention, parallel to those described earlier in our consideration of human history. This parallel becomes even clearer when we recognize that standing in a reciprocal relation to traditional patterns of tree simplification and differential resolution, and similarly dependent upon a perspectival view of the evolutionary past, is a canon of events that are taken to have been key innovations in the course of evolutionary history. Previously (O'Hara 1988a) I described how statements about such key innovations are narrative in character since they depend upon knowledge of other events which happen long after the particular event in question. It is equally important to realize here, however, that the selection of particular events as key depends entirely upon the metahistorical standpoint of the selector. Would any of the teleosts see the following as a true account of vertebrate history?

Our story of vertebrates has so far been that of primitive water dwellers – fish and fishlike forms. This evolutionary history has not been unmarked by progressive features, for we have witnessed the appearance of jaws and paired fins, structures whose development enabled our earliest mud-grubbing ancestors to leave their sluggish life on the bottoms and become active, aggressive forms. But the greatest adventure of all still lay ahead for the backboned animals – the conquest of the land, a feat which led to the development of higher groups of four-footed terrestrial vertebrates. (Romer 1959, p. 87)

By treating the vertebrate clade as an ontological individual (O'Hara 1988a, p. 153; compare Wiley 1980, p. 78), and by looking at the past from the human standpoint alone, Romer is able to identify certain events (the origin of jaws and the “conquest” of the land) as key occurrences for the vertebrates.

So successful has been this view of evolution and so entrenched is the canon of evolutionary events that both have taken on a mythological character. An additional illustration (Figure 7), also part of the “Tower of Time” exhibit at the National Museum of Natural History, makes this point vividly. Its lower portion represents the origin of jaws (and meanwhile, in the narrative background, plants invading the land), while its upper portion shows the development of tetrapod limbs and the imminent “conquest” of the land. Repeated again and again in biology textbooks and popular surveys, this story has become part of the great evolutionary epic, and it is perpetuated by many tellers independent of the technical literature.

The epic story-teller is telling a traditional story. The primary impulse which moves

him is not a historical one, nor a creative one; it is *re-creative*. His primary allegiance is not to fact, not to truth, not to entertainment, but to the *mythos* itself – the story as preserved in the tradition which the epic story-teller is re-creating. The word *mythos* meant precisely this in ancient Greece: a traditional story. (Scholes and Kellogg 1966, p. 12)

So powerful is the traditional canon of evolutionary events that it has even drawn the attention of two of science's most trenchant commentators (Larson 1989, p. 232; Gonick 1990, p. 24).

#### TELLING THE TREE

If narrative modes of representation invariably produce perspectival accounts of the evolutionary past, then what should natural historians do? Should they be content with perspectival accounts, or should they try to discover some narratively neutral or non-narrative mode of historical representation? How should they tell the tree?

One solution to the problem of perspective might be to attempt to achieve an inter-perspectival understanding of evolution, on the model of the inter-perspectival understandings of history discussed above (Dray 1989). Even though no other taxa are capable of writing evolutionary histories, we might nevertheless be able to imaginatively adopt the point of view of another taxon ourselves, and write a narrative evolutionary history consonant with that point of view. ("The anarthropods are a primitive group with few species and a limited diversity of form. Their low reproductive rates prevent them from adapting to their environments closely, and the gigantism exhibited by many anarthropods has kept their numbers very low and is no doubt the cause of their general sluggishness".<sup>4</sup>) If we had, to accompany the traditional vertebrate story, a series of evolutionary "Grendels", then we might be able to achieve the same sort of roundabout understanding of evolutionary history that Dray proposed for history itself. If nothing else, the existence of a collection of such narratives might help to break the grip of the traditional evolutionary *mythos*, derived from the Chain of Being, by showing it for what it is: not the story of life, but the story of events which have been important in the history of us (de Queiroz 1988, p. 252).

An alternative solution might be to strive to make our representations of evolutionary history narratively neutral. It may not be possible to do this completely, but the narrativity of many evolutionary histories could be reduced considerably in a number of ways. Abandoning the notion of taxonomic rank would go a long way toward eliminating sequences of contemporary taxa, because sequences are most often created out of collections of taxa of equal rank (see Mayr and Greenway 1956 for an example). And while taxa may be referred to as ancestral or descendant, or as older or younger, *taxa* should never be referred to as primitive or derived or higher or lower (de Queiroz 1988, p. 252); the terms primitive and derived should be reserved for character states, and the terms higher and lower should be abandoned, as Darwin recommended more



Fig. 7. Two of the principal events in the evolutionary canon. Below, the origin of jaws (with plants invading the land in the narrative background), and above, the development of the tetrapod limb and the “conquest” of the land. From a color painting by John Gurche, part of the “Tower of Time” exhibit at the National Museum of Natural History; reproduced in Lewin (1982) and Reader (1986). (Reprinted courtesy of the Smithsonian Institution.)

than 150 years ago. In phylogenetic diagrams, the branches of living sister taxa should be of equal length to represent their equal ages; if it is desired to indicate that they have changed by different amounts according to some particular measure then that should be shown alongside their branches. It should always be made clear in a tree diagram that it is the topological relations of the branches that carries meaning, and not their left-to-right positioning; sister clades can always be rotated around their ancestral node arbitrarily. Differential resolution will be a more difficult problem to correct, since it is not entirely clear, except perhaps at the species level, and in hypothetical cases like Figure 5, what exactly balanced resolution would be. Cases of gross imbalance, however, like that in Figures 1 and 4, should be fairly easy to remedy. The hierarchy of life should remind us less of a ladder or a story or a "mental map", than of a "garden of forking paths" (Borges 1964) or one of those pictures of the Milky Way galaxy in which a small arrow is placed in one corner over the caption "You are here". If it is necessary to show some particular section of a tree in greater detail than another, this should be done by means of an inset, according to the common practice of cartographers (the plate "The Universe" in the *National Geographic Atlas of the World* (National Geographic Society 1990) could serve as an excellent example).

In the end it may be necessary to combine both of these approaches. Narratively neutral diagrams may indeed provide us with the best means of representing the evolutionary past in works from now on, but in order to loosen the hold of the traditional accounts, collections of more standard narratives written from a variety of evolutionary perspectives may be needed as well.

There is in the United States today a popular newspaper comic strip called *Calvin and Hobbes*, in which a small boy (Calvin) and his stuffed tiger (Hobbes) explore the mysteries of nature, society, and the imagination. In a recent episode, Calvin related his discovery that "History is a force. Its unalterable tide sweeps all people and institutions along its unrelenting path. Everything and everyone serves history's single purpose". When Hobbes enquires, rather skeptically, just what this purpose is, Calvin replies, with all the confidence of childhood, "Why, to produce *me*, of course! I'm the end result of history".

The steps that must be taken in evolutionary biology to leave the "Calvin" in ourselves behind, to leave behind our ancient self-centeredness, will be difficult. "Group thinking" (O'Hara 1988a, p. 151), evolutionary narratives, phylogenetic sequences, canonical schemes of attention, notions of taxa themselves being primitive or derived instead of primitive or derived with respect to particular characters, are all so deeply a part of our traditional view of our place in Nature that they will be difficult to dislodge. The recent history of systematics shows that this is so. What we have seen in the recent history of systematics is not simply a dispute over methods and objects; what we have seen, and continue to see, is the dying struggle of the Great Chain of Being. The abandonment of paraphyletic groups, the abandonment of taxonomic rank (Patterson 1988; Gauthier et al. 1989), the abandonment of phylogenetic sequences and naive

evolutionary narratives, these are all manifestations of a very deep cosmological reordering, the full implications of which remain to be seen. The emotional energy which has been expended in the discussion of these issues (documented by Hull 1988) is a further indication of the profound nature of the change. In the words of Toulmin (1982, p. 165): "The intellectual landmines laid for us by Charles Darwin more than a century ago continue to explode".

But just as we survived our removal from the center of the solar system, so too will we survive our removal from the top of the evolutionary tree, and from the end of history. When we come to realize that even among the vertebrates there are 50,000 different "vertebrate stories", each one with a different ending and each one with a different narrative landscape; when we truly think in terms of the diverging tree, instead of the line; when we understand that it is absurd to talk of one animal being higher than another; only then will we see the full grandeur of the historical view of life.

#### ACKNOWLEDGEMENTS

Earlier versions of this paper were presented at meetings of the American Society of Zoologists, the Society of Systematic Zoology, and the Willi Hennig Society, and at the conference on Philosophical Problems in Evolutionary Biology at the University of Otago. For travel assistance I am grateful to P. E. Griffiths, R. W. Thorington, Jr., Q. D. Wheeler, and R. L. Zusi, and for assistance with the mathematics of tree simplification I am grateful to D. S. Fry. Photographs of some of the figures were taken by V. Krantz and C. Clark. For their comments on the ideas here discussed I thank G. Currie, G. R. Graves, P. E. Griffiths, G. C. Mayer, A. Musgrave, K. de Queiroz, P. F. Stevens, and R. L. Zusi, and the participants in several LISTSERV electronic discussion groups, including [INGRAFX@PSUVM](mailto:INGRAFX@PSUVM), [PHILOSOP@YORKVM1](mailto:PHILOSOP@YORKVM1), and [PMC-TALK@NCSUVM](mailto:PMC-TALK@NCSUVM). This research was supported in part by a postdoctoral fellowship in the Division of Birds, National Museum of Natural History, Smithsonian Institution.

#### NOTES

<sup>1</sup> The range of topics that are being studied from a narrative perspective is now widening even beyond history and literature. For an example, see the recent paper by Rouse (1990) which characterizes the understandings that scientists have of their own disciplines in narrative terms.

<sup>2</sup> As this paper was being submitted for publication Landau's study (1991) of paleoanthropological narratives appeared. Her work differs from mine in examining accounts of the human lineage exclusively, and in focussing on common modes of emplotment.

<sup>3</sup> Comparative studies of traditional patterns of systematic resolution and "mental maps" might also shed light on the remarkable movement toward "neural classification" in

botany (see Stevens 1990). Advocates of "neural classification" suggest that systematists should formally recognize those groupings that the human mind most naturally recognizes. This would be analogous to saying that because people "naturally" perceive geographical space with an observer-centered distortion (as in "A Bostonian's View of the World") professional cartographers ought to actually draw all their maps that way.

<sup>4</sup> An example of this sort that has actually been used, though with a slightly different purpose in mind, is the famous lecture of Professor Ichthyosaurus on the structure of the human skull, from Buckland (1874), and reproduced by Gould (1987, p. 98): "'You will at once perceive', continued Professor Ichthyosaurus, 'that the skull before us belonged to some of the lower order of animals; the teeth are very insignificant, the power of the jaws trifling, and altogether it seems wonderful how the creature could have procured food'".

## REFERENCES

- American Ornithologists' Union: 1983, *Check-list of North American Birds*, sixth edition, American Ornithologists' Union.
- Atran, S.: 1990, *Cognitive Foundations of Natural History: Towards an Anthropology of Science*, Cambridge University Press, Cambridge.
- Bailyn, B.: 1967, *The Ideological Origins of the American Revolution*, Harvard University Press, Cambridge.
- Barrett, P. H.: 1960, 'A Transcription of Darwin's First Notebook on "Transmutation of Species"', *Bulletin of the Museum of Comparative Zoology* 122, 247-296.
- Bonnet, C.: 1745, *Traité d'Insectologie, Premier Parte*, Durand, Paris.
- Borges, J. L.: 1964, 'The Garden of Forking Paths', in *Labyrinths: Selected Stories and Other Writings*, New Directions, New York, pp. 19-29.
- Buckland, F.: 1874, *Curiosities of Natural History*, Richard Bentley and Son, London.
- Butterfield, H.: 1931, *The Whig Interpretation of History*, George Bell & Sons, London.
- Carroll, R. L.: 1988, *Vertebrate Paleontology and Evolution*, W. H. Freeman and Company, New York.
- Danto, A. C.: 1985, *Narration and Knowledge*, Columbia University Press, New York.
- Downs, R. M., and D. Stea: 1977, *Maps in Minds: Reflections on Cognitive Mapping*, Harper & Row, New York.
- Dray, W.: 1989, *On History and Philosophers of History*, E. J. Brill, Leiden.
- Durrell, L.: 1957, *Justine*, E. P. Dutton & Co., Inc., New York.
- Durrell, L.: 1958, *Balthazar*, E. P. Dutton & Co., Inc., New York.
- Durrell, L.: 1959, *Mountolive*, E. P. Dutton & Co., Inc., New York.
- Fernholm, B., K. Bremer, L. Brundin, H. Jörmvall, L. Rutberg, and H.-E. Wanntorp (organizing committee): 1989, *The Hierarchy of Life: Molecules and Morphology in Phylogenetic Analysis*, Proceedings from Nobel Symposium 70, Excerpta Medica, Amsterdam, New York, and Oxford.
- Feyerabend, P. K.: 1988, *Against Method*, revised edition, Verso, London.
- Gallie, W. B.: 1964, *Philosophy and the Historical Understanding*, Schocken Books, New York.
- Gardner, J.: 1971, *Grendel*, Knopf, New York.
- Gauthier, J., D. Cannatella, K. de Queiroz, A. G. Kluge, and T. Rowe: 1989, 'Tetrapod Phylogeny', in B. Fernholm et al. (eds.), *The Hierarchy of Life*, Excerpta Medica, Amsterdam, pp. 337-353.
- Gonick, L.: 1990, *The Cartoon History of the Universe*, Doubleday, New York.
- Gould, P., and R. White: 1986, *Mental Maps*, second edition, Allen & Unwin, Boston.
- Gould, S. J.: 1987, *Time's Arrow, Time's Cycle*, Harvard University Press, Cambridge.
- Gould, S. J.: 1989, *Wonderful Life: The Burgess Shale and the Nature of History*, W. W.



- Norton & Company, New York.
- Greene, J. C.: 1961, *The Death of Adam*, Mentor Books, New York.
- Haynes, R. M.: 1980, *Geographical Images and Mental Maps*, Macmillan Education Ltd., Houndmills.
- Hull, D. L.: 1988, *Science as a Process*, University of Chicago Press, Chicago.
- Landau, M.: 1991, *Narratives of Human Evolution*, Yale University Press, New Haven.
- Larson, G.: 1989, *The Prehistory of the Far Side: A 10th Anniversary Exhibit*, Andrews and McMeel, Kansas City.
- Lewin, R.: 1982, *Thread of Life: The Smithsonian Looks at Evolution*, Smithsonian Books, Washington, D. C.
- Lovejoy, A. O.: 1936, *The Great Chain of Being*, Harvard University Press, Cambridge.
- Mallory, J. P.: 1989, *In Search of the Indo-Europeans: Language, Archeology and Myth*, Thames and Hudson, London.
- Mayr, E., and J. C. Greenway, Jr.: 1956, 'Sequence of Passerine Families (Aves)', *Breviora* 58.
- Mink, L. O.: 1987, *Historical Understanding*, Cornell University Press, Ithaca.
- Nagel, E.: 1959, 'The Logic of Historical Analysis', in H. Meyerhoff (ed.), *The Philosophy of History in Our Time*, Doubleday, Garden City, pp. 203–215.
- National Geographic Society: 1990, *National Geographic Atlas of the World*, sixth edition, National Geographic Society, Washington, D. C.
- Nitecki, M. H. (ed.): 1988, *Evolutionary Progress*, University of Chicago Press, Chicago.
- O'Hara, R. J.: 1988a, 'Homage to Clio, or, Toward an Historical Philosophy for Evolutionary Biology', *Systematic Zoology* 37, 142–155.
- O'Hara, R. J.: 1988b, 'Diagrammatic Classifications of Birds, 1819–1901: Views of the Natural System in 19th-Century British Ornithology', in H. Ouellet (ed.), *Acta XIX Congressus Internationalis Ornithologici*, National Museum of Natural Sciences, Ottawa, pp. 2746–2759.
- O'Hara, R. J.: 1991, 'Representations of the Natural System in the Nineteenth Century', *Biology and Philosophy* 6, 255–274.
- Patterson, D. J.: 1988, 'The Evolution of Protozoa', *Memorias do Instituto Oswaldo Cruz, Rio de Janeiro, Suplemento I* 83, 580–600.
- de Queiroz, K.: 1988, 'Systematics and the Darwinian Revolution', *Philosophy of Science* 55, 238–259.
- Raikow, R. J.: 1986, 'Why Are There so Many Kinds of Passerine Birds', *Systematic Zoology* 35, 255–259.
- Raikow, R. J.: 1988, 'The Analysis of Evolutionary Success', *Systematic Zoology* 37, 76–79.
- Reader, J.: 1986, *The Rise of Life: The First 3.5 Billion Years*, Knopf, New York.
- Richards, R. J.: 1987, *Darwin and the Emergence of Evolutionary Theories of Mind and Behavior*, University of Chicago Press, Chicago.
- Romer, A. S.: 1959, *The Vertebrate Story*, fourth edition, University of Chicago Press, Chicago.
- Rouse, J.: 1990, 'The Narrative Reconstruction of Science', *Inquiry* 33, 179–196.
- Savage, H. M.: 1983, 'The Shape of Evolution: Systematic Tree Topology', *Biological Journal of the Linnean Society* 20, 225–244.
- Scholes, R., and R. Kellogg: 1966, *The Nature of Narrative*, Oxford University Press, New York.
- Shao, K.-T., and R. R. Sokal: 1990, 'Tree Balance', *Systematic Zoology* 39, 266–276.
- Sloan, P. R.: 1987, 'From Logical Universals to Historical Individuals: Buffon's Idea of Biological Species', in *Histoire du Concept d'Espèce dans les Sciences de la Vie*, Fondation Singer-Polignac, Paris, pp. 101–140.
- Stevens, P. F.: 1990, 'Nomenclatural Stability, Taxonomic Instinct, and Flora Writing – a Recipe for Disaster?', in P. Baas et al. (eds.), *The Plant Diversity of Malesia*, Kluwer Academic Publishers, Dordrecht, pp. 387–410.

- Toulmin, S.: 1982, *The Return to Cosmology: Postmodern Science and the Theology of Nature*, University of California Press, Berkeley.
- Toulmin, S.: 1988, 'The Recovery of Practical Philosophy', *American Scholar* 57, 337–352.
- Toulmin, S.: 1990, *Cosmopolis: The Hidden Agenda of Modernity*, The Free Press, New York.
- Toulmin, S., and J. Goodfield: 1965, *The Discovery of Time*, Harper & Row, New York.
- White, H.: 1973, *Metahistory: The Historical Imagination in Nineteenth-Century Europe*, Johns Hopkins University Press, Baltimore.
- White, H.: 1987, *The Content of the Form*, Johns Hopkins University Press, Baltimore.
- White, M.: 1965, *Foundations of Historical Knowledge*, Harper & Row, New York.
- Wiley, E. O.: 1980, 'Is the Evolutionary Species Concept Fiction? – A Consideration of Classes, Individuals and Historical Entities', *Systematic Zoology* 29, 76–80.