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New Perspectives on the History of Life

MAPPING THE SPACE OF TIME: TEMPORAL REPRESENTATION IN THE HISTORICAL SCIENCES

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> As to the propriety and justness of representing sums of money, and time, by parts of space, tho' very readily agreed to by most men, yet a few seem to apprehend that there may possibly be some deception in it, of which they are not aware. . . .
>
> William Playfair, 1786, in Tufte (1983:52)

Introduction: The Palaetiological Sciences

William Whewell (1794–1866), polymathic Victorian scientist, philosopher, historian, and educator, was one of the great neologists of the nineteenth century. Although Whewell's name is little remembered today except by professional historians and philosophers of science, researchers in many scientific fields work each day in a world that Whewell named. "Miocene" and "Pliocene," "uniformitarian" and "catastrophist," "anode" and "cathode," even the word "scientist" itself— all of these were Whewell coinages. Whewell is particularly important to students of the historical sciences for another word he coined, one that was unfortunately not as successful as many of his others because it is difficult to pronounce. This word, "palaetiology," was the name Whewell gave to the class of sciences that are concerned with historical causation: the class we might today refer to as historical sciences. Although the disciplines Whewell included under the heading of palaetiology might seem to cut across the conventional academic boundaries of his day and ours — his exemplars were geology and comparative philology — all these fields may nevertheless be examined together, Whewell argued, because of their common interest in reconstructing the past. Just as we may look back, he said,

> towards the first condition of our planet, we may in like manner turn our thoughts towards the first condition of the solar system, and try whether we can discern any traces of an order of things antecedent to that which is now established; and if we find, as some great mathematicians have conceived, indications of an earlier state in which the planets were not yet gathered into their present forms, we have, in pursuit of this train of research, a palaetiological portion of Astronomy. Again, as we may inquire how languages, and how man, have been diffused over the earth's surface from place to place, we may make the like inquiry with regard to the races of plants and animals, founding our inferences upon the existing geographical distribution of the animal and vegetable kingdoms: and thus the Geography of Plants and of Animals also becomes a portion of Palaetiology. Again, as we can in some measure trace the progress of Arts from nation to nation and from age to age, we can also pursue a similar investigation with respect to the progress of Mythology, of Poetry, of Government, of Law. . . . It is not an arbitrary and useless proceeding to construct such a Class of sciences. For wide and various as their subjects are, it will be found that they have all certain principles, maxims, and rules of procedure in common; and thus may reflect light upon each other by being treated together.
>
> (Whewell, 1847, 1:639-640)

This paper is an essay on the palaetiological sciences, dedicated to Whewell on the bicentennial of his birth, an essay that examines some of the "principles, maxims, and rules of procedure" that these sciences have all in common. Its first purpose is to demonstrate the continuing validity of Whewell's classification of these sciences through a study of historical representation in three different palaetiological fields: systematics, historical linguistics, and textual transmission. Its second purpose is to continue the development of an extended analogy between historical representation and cartographic representation that I began in an earlier paper (O'Hara, 1993), an analogy that makes especially clear the common representational practices that are found throughout palaetiology.

To set the stage for what is to follow, I offer here three diagrams, one each from the different palaetiological fields of systematics, historical linguistics, and textual transmission or stemmatics, three diagrams all drawn independently within 40 years of each other in the mid-nineteenth century. The first of these (Fig. 1), familiar to all evolutionary biologists, is Darwin's tree of descent from the *Origin of Species* (1859). The vertical axis of this diagram represents time, while each horizontal line marks an interval of some number of generations: a thousand, or a million, or a hundred million (1859:116–126). Figure 2 is less familiar, even to specialists in the field from which it comes, historical linguistics. This

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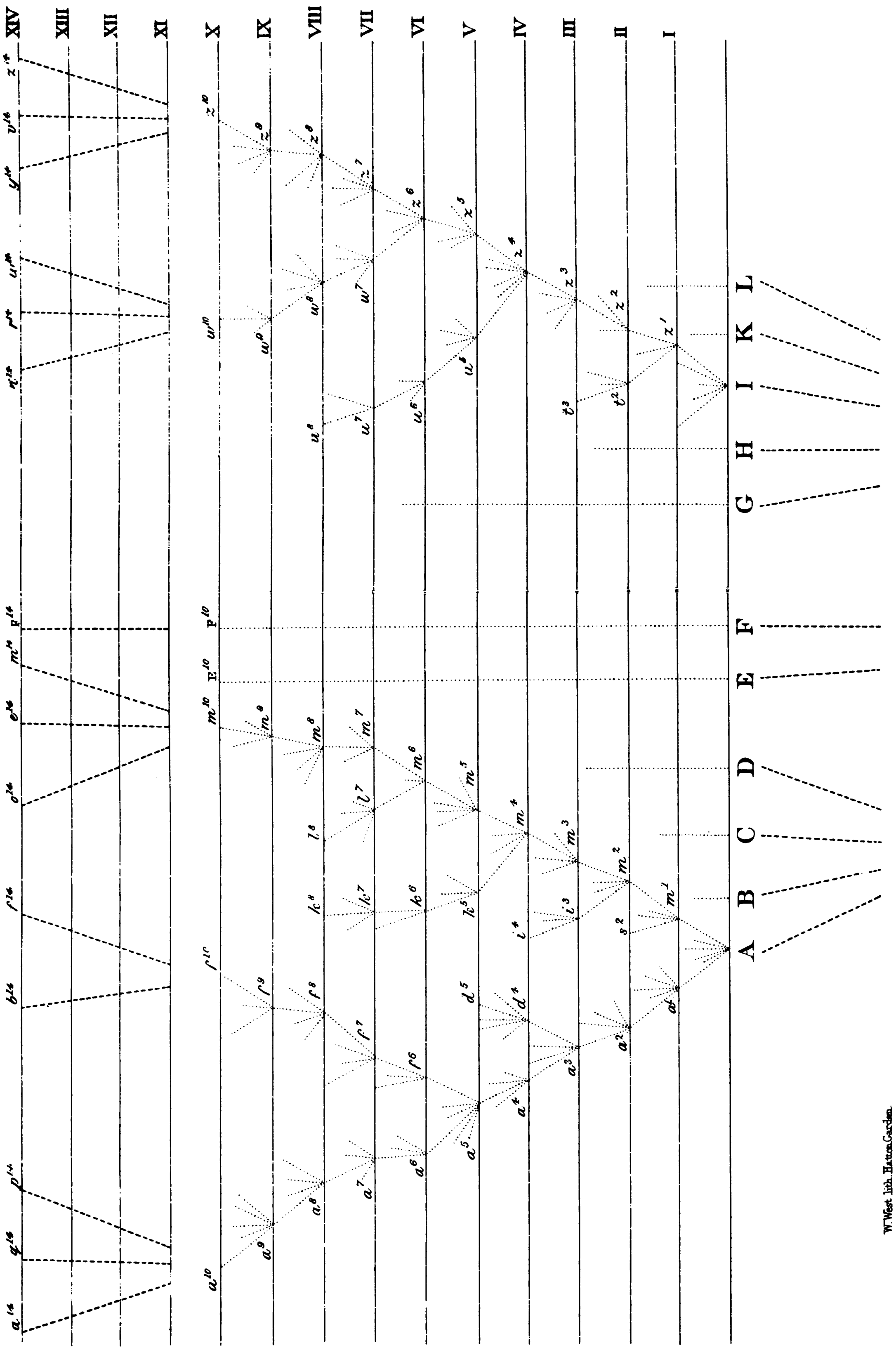

FIGURE 1. The hypothetical tree of life from Darwin's *Origin of Species* (1859). The vertical axis represents time, with each division standing for some arbitrary number of generations.

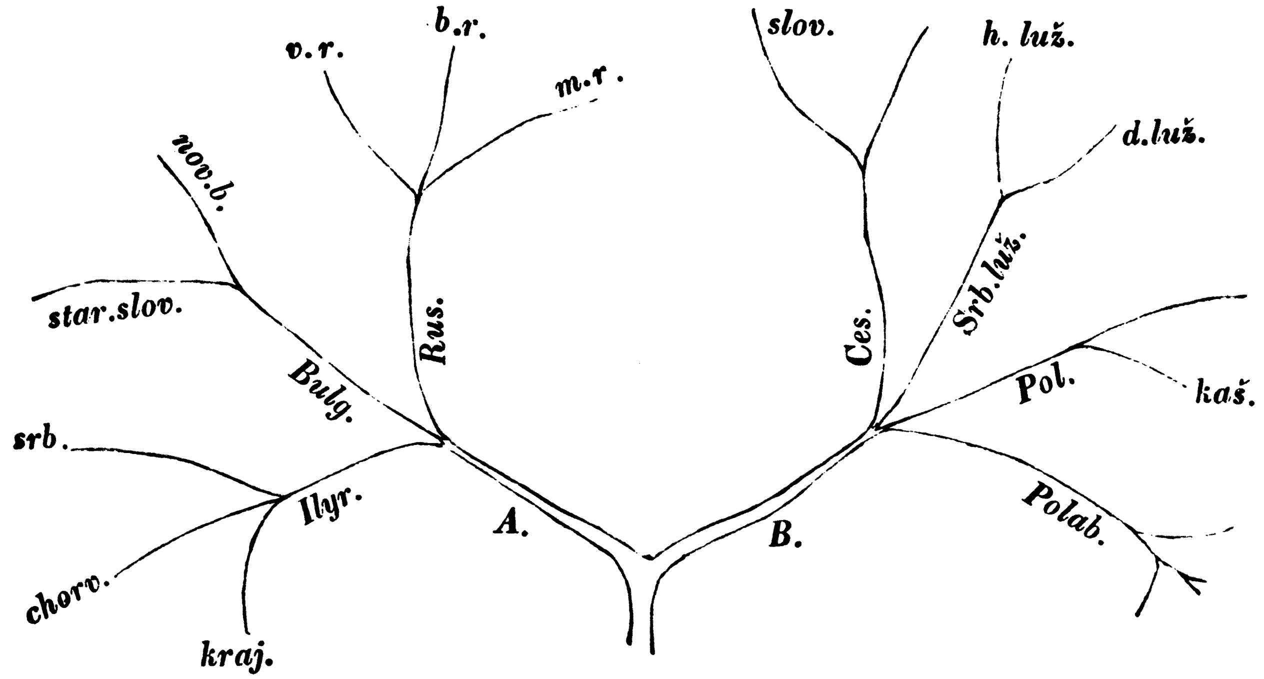

FIGURE 2. A genealogy of the Slavic languages drawn by František Celakovsky at Prague about 1852 and published in 1853 shortly after his death (Celakovsky, 1853; Priestly, 1975). For the only language tree earlier than Celakovsky's (a diagram drawn around 1800 by Félix Gallet) see Auroux (1990).

diagram is one of the first trees of language "phylogeny" and it was drawn, like Darwin's tree in the 1850s, by the Bohemian historical linguist František Celakovsky (Celakovsky, 1853; Priestly, 1975). Figure 3 is a third "tree of history": the first stemma of manuscript transmission, published by Carl Johan Schlyter in 1827 (Collin and Schlyter, 1827; Holm, 1972). As in Darwin's diagram, the vertical axis represents time, and each horizontal line stands for a specific time interval (25 years in this case). What these three diagrams illustrate is that three palaetiological sciences — systematics, historical linguistics, and textual transmission — though they function independently, all produce results of the very same sort using many of the same procedures of inference: they all produce trees of history showing branching sequences of ancestry and descent.

In each of these fields a great deal of attention has been given to the methods of historical reconstruction, particularly so in recent years in systematics, where attention has also been given to the historical character of the discipline as a whole (O'Hara, 1988a; de Queiroz, 1988; Ghiselin, 1991). But in contrast to the amount of attention that has been given to historical *reconstruction* (e.g. Sober, 1988), very little has been written in any of these fields about the problems of historical *representation*. Given that we have knowledge about events that took place in the past — the geological past, or the evolutionary past, or the linguistic or textual past — how do we represent, how do we communicate that knowledge? In particular, how do we use diagrams, which are two-dimensional, *spatial* representations, to depict the *temporal* relationships of events in time?

It might seem that historical representation (as opposed to historical reconstruction) is unproblematic: historical scientists just draw diagrams that illustrate what they know. Historical representation is a more subtle activity than one might suspect, however, and I want to demonstrate this by comparing historical representation — the representation of events in time — with cartographic representation — the representation of objects in space, as we see in ordinary geographical maps. Maps might also seem to be completely unproblematic representations of the world, but in fact they too are rather more subtle than one might expect. In making this comparison I will draw heavily on the work done by cartographic theorists (Toulmin, 1953; Robinson and Petchenik, 1976; Gould and White, 1986; Buttenfield and McMaster, 1991; Monmonier, 1991; McMaster and Shea, 1992), as well as some of my own earlier work on diagrams in systematics (O'Hara, 1988b, 1991, 1992, 1993).

Maps as Spatial Representations

Maps are representations of objects in space, and they succeed as representational devices because they are *selective*: because they omit a great deal of information that map-makers in fact have. Some imaginary Ideal Map that included literally everything in the territory it represented would be useless, because the territory itself could serve just as well (Crampton, 1990; O'Hara, 1993). Cartographers call the process whereby the world is reduced to a map, or a complex map reduced to a simpler map, *cartographic generalization*. The most basic element of the generalization process is the simple deletion of certain objects from the map, objects that exist on the earth but that will not appear on the map. But many other processes are involved in generalization as well, beyond the simple deletion of objects. For example, areal features may have their outlines simplified, and linear features may be smoothed or enhanced (Fig. 4; Monmonier, 1991). A surprising element of generalization is "feature displacement": when two objects are so close together on a map that they are difficult to distinguish, and yet both must be included, the two objects may be nudged apart slightly (Fig. 4). This has the effect of warping the scale of the map in the vicinity of the displaced objects: a unit of distance on the map in that region corresponds to a shorter distance on the ground than does the same unit of distance on another part of the map.

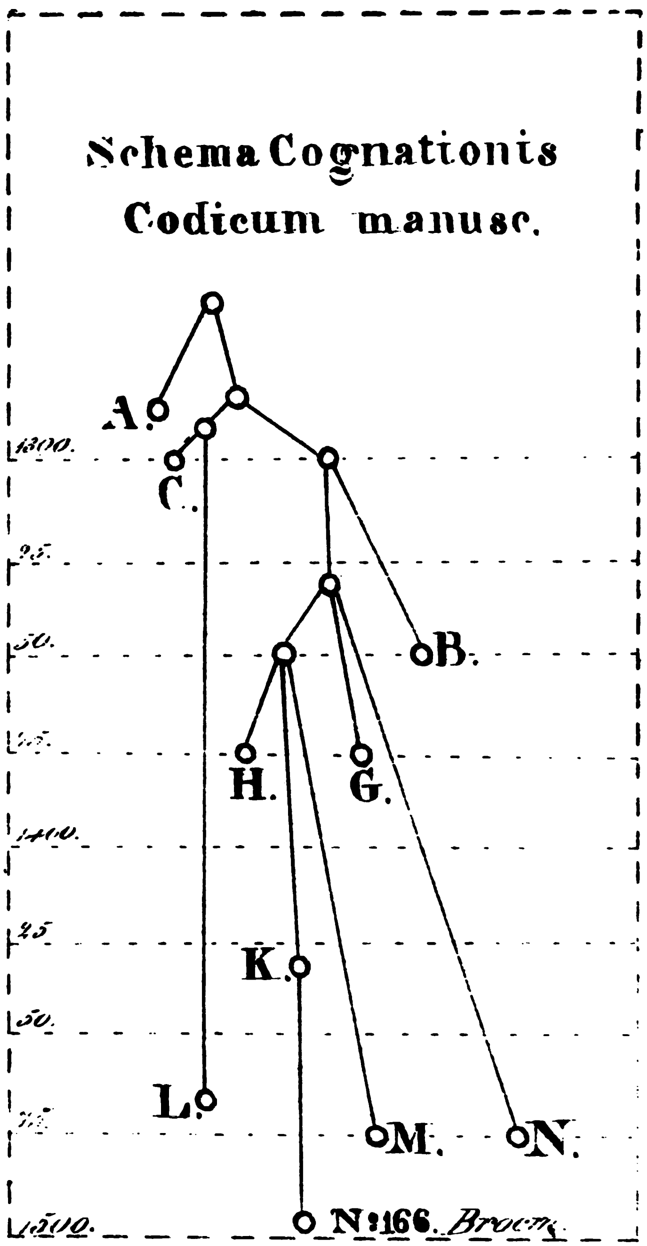

FIGURE 3. Carl Johan Schlyter's stemma of a group of medieval Swedish legal texts, the first diagram of textual transmission ever published (Collin and Schlyter, 1827; Holm, 1972). Notice the remarkable similarity to Darwin's evolutionary diagram, with the vertical axis representing absolute time and horizontal lines indicating time intervals.

Cartographic generalization is a concept that has been developed and applied in the context of geographic maps, and one might think at first that such a concept would have little relevance to representations of history — to representations of events in time rather than objects in space. But upon reflection it is evident that we often speak of space and time in the same terms, and so ideas that apply in one domain might well be useful in the other. "Short" and "long" are adjectives that apply to "lengths" of both space and time. We speak of "deep" time and the "distant" past. And in answer to the question "How far is it to the city?" one is as likely to be told "two hours" as "100 miles." In view of the similarity between the language of space and the language of time, then, let us see if the notion of generalization can be applied with as much success to representations of events in time (events as they are reconstructed by palaetiologists) as it has been by cartographers to representations of objects in space.

The Space of Time

Let us begin with the simple case of an historical diagram that is strikingly cartographic in character (Fig. 5). This diagram of phylogeny from Hennig's well-known systematics text (1966) shows a sequence of events at three different temporal scales, two of them by means of insets, just as a city map might have an inset to show the city center and another to show the surrounding region. Apparent in this diagram is a temporal equivalent of what cartographers call aggregation, as when several small lakes are shown on a map as one larger lake. Temporal aggregation is manifest here in the representation of several generations of individual organisms by a single circle in the inset on the right. Similarly, even though each individual organism itself has a temporal dimension (its life span), each is reduced in Figure 5 to a single symbol without temporal extent. This latter phenomenon is called symbolization in cartography, when an object that occupies a definite geographical area (a city, for example) is reduced to a single symbol such as a dot.

In the broad spirit of palaetiology, it is important to realize that these phenomena of temporal generalization are not restricted to evolutionary trees alone, as can be seen in Figures 6 and 7, two recently-published diagrams of the history of the Germanic languages. Figure 6 shows a simplified (highly generalized) version of the entire Germanic tree, ending in the three branches of East Germanic, North Germanic, and West Germanic, the last of these being the branch that includes modern English. Figure 7 shows an enlargement of the West Germanic branch alone: the single lower right branch of Figure 6 corresponds to the entirety of Figure 7, just as an irregular polygon representing the city of San Fran-

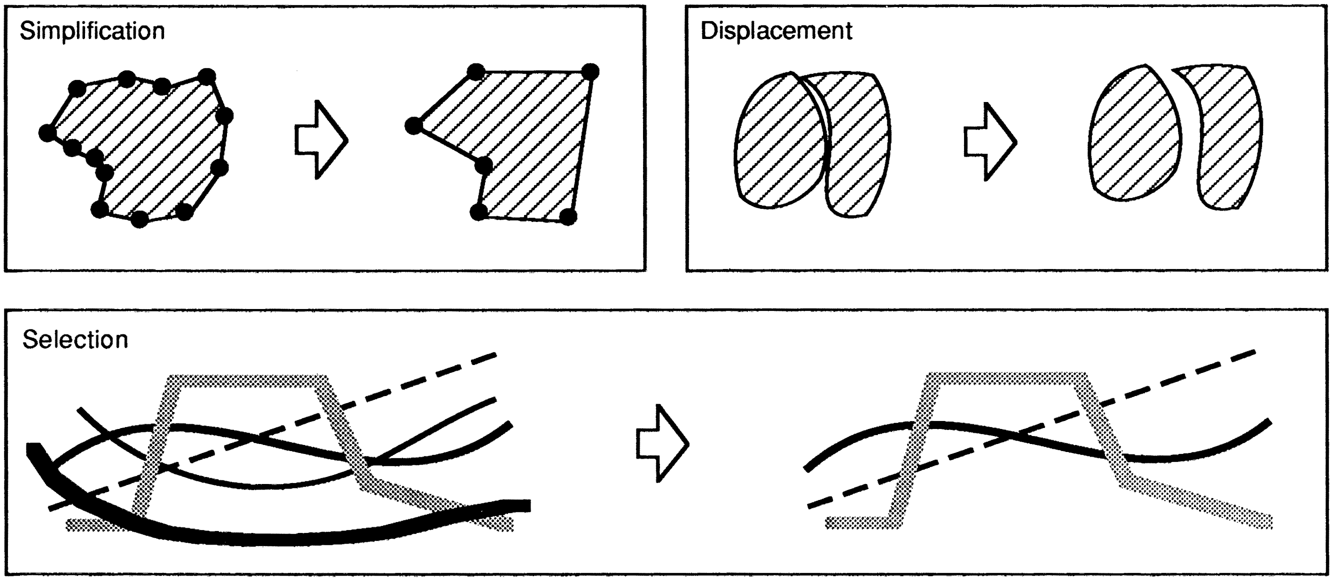

FIGURE 4. Some elements of cartographic generalization, redrawn after Monmonier (1991).

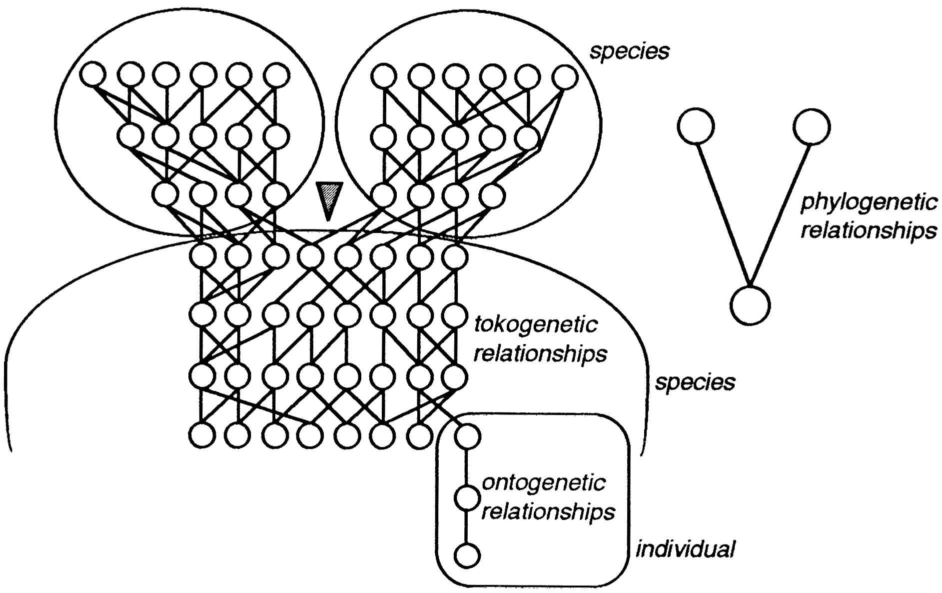

FIGURE 5. A hypothetical phylogeny, after Hennig (1966). Three different degrees of generalization are shown: the central portion of the diagram is resolved to the level of individual organisms, while the inset at the bottom shows the life stages of one individual, and the inset at the right shows a coarser view of the species as a whole. See O'Hara (1993) for further discussion of diagrams of this type, and see Maddison and Maddison (1992:26) for an additional example.

cisco on a map of California would correspond to an entire San Francisco street map.

As a representation of objects in space, any geographical map can be generalized in a number of different ways. We could take a detailed map of San Francisco and generalize it into a map showing only the subway lines, or only the railroads, or only the public streets and nothing else. Similarly, any given representation of events in time, such as an evolutionary tree, can also be generalized in a number of different ways (O'Hara, 1993). And just as different generalizations of a map may give the viewer different senses of a particular territory — one that showed all the parks might give a different impression from one that showed only highways and railroad tracks (Monmonier, 1991) — so also different generalizations of a detailed sequence of events in time may give the viewer different senses of what took place within a particular temporal space. Different generalizations of the history of life, for example, may give the impression that evolution is either directed or diversifying (O'Hara, 1992, 1993).

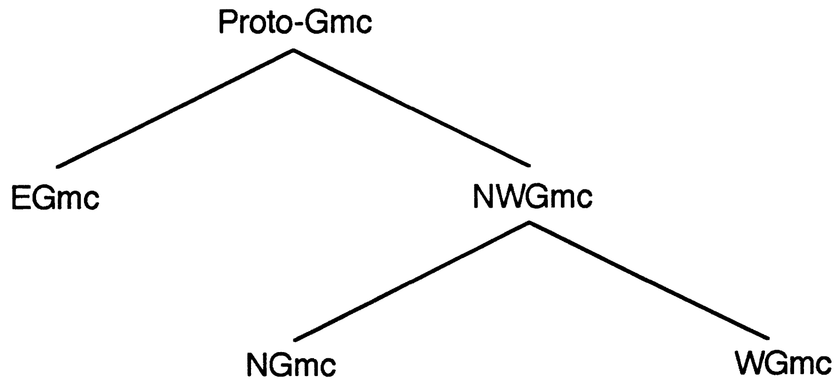

FIGURE 6. A simplified (highly generalized) history of the Germanic languages, after Barber (1993). The ancestral Proto-Germanic language is shown dividing into East and Northwest Germanic branches, the latter dividing again into North and West Germanic. The West Germanic branch, of which modern English is a part, is shown in greater detail in Figure 7.

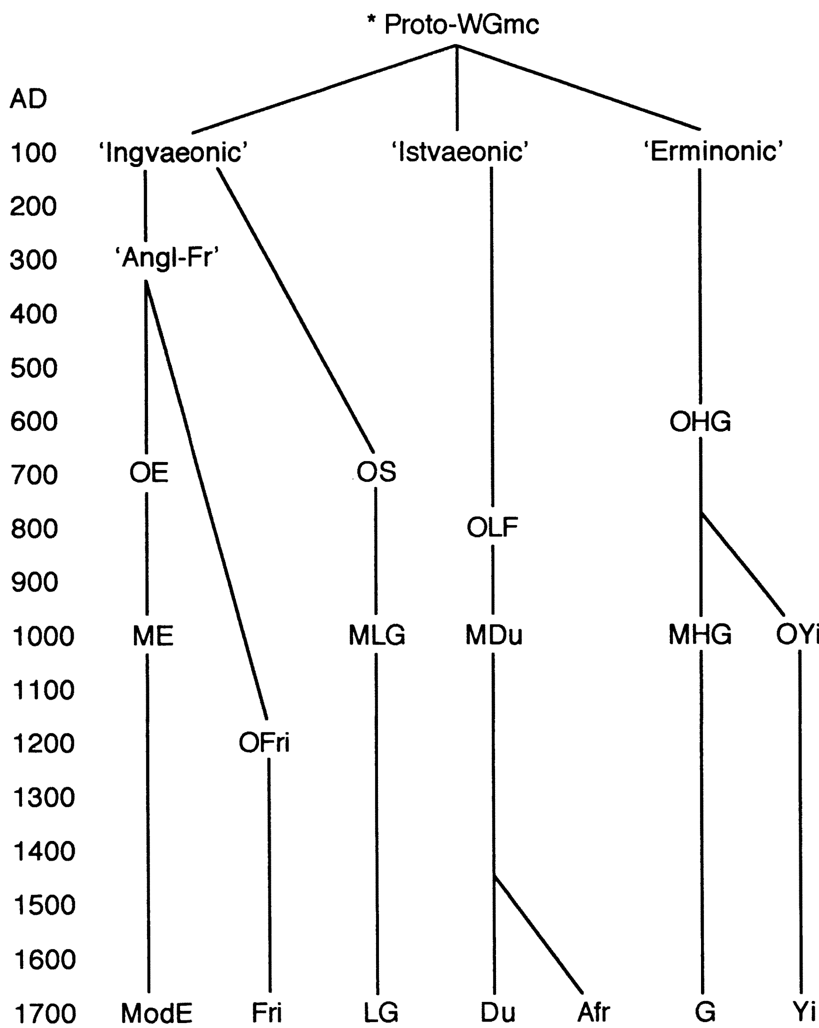

FIGURE 7. A detailed history (relatively un-generalized) of the West Germanic languages, after Barber (1993). The terminal branches shown are Modern English (ModE), Frisian (Fri), Low German (LG), Dutch (Du), Afrikaans (Afr), German (G), and Yiddish (Yi). This diagram is a more highly resolved representation of the lower right branch (WGmc) in Figure 6.

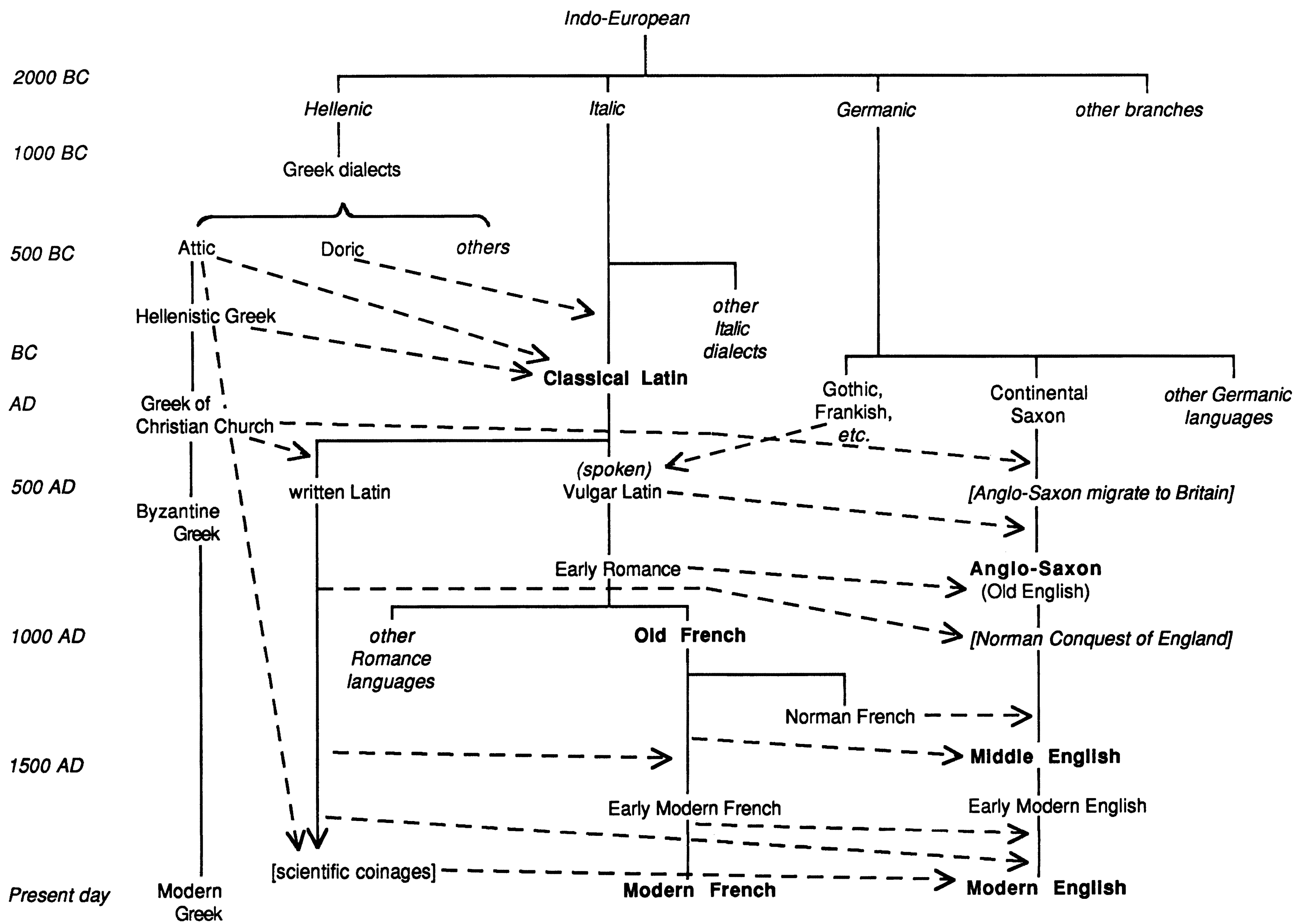

FIGURE 8. A genealogy of selected Indo-European languages, after Powell (1988). In contrast to Figures 6 and 7, which depict only direct transmission, this tree shows not only direct transmission but also borrowing of language elements across the tree.

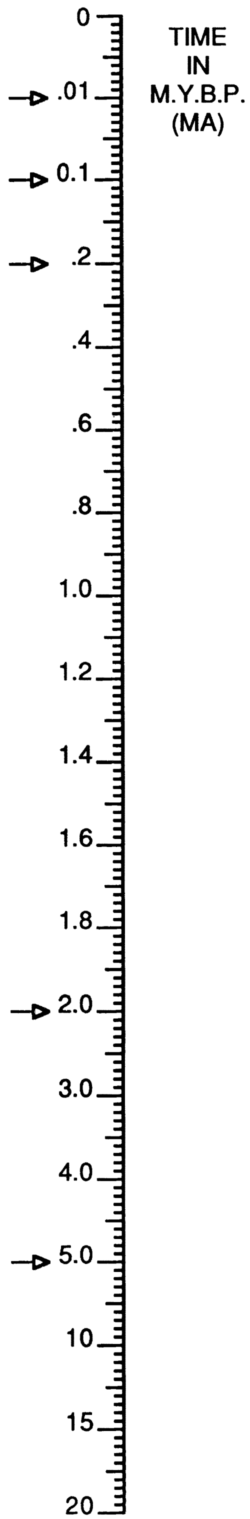

FIGURE 9. A portion of a geological time scale, redrawn after Haq and Van Eysinga (1987). The linear scale stretches out toward the present so that more events can be included. This stretching of the temporal space is equivalent to the practice of feature displacement in cartography, but when it is carried to this extreme in cartography the effect is usually regarded as humorous.

Again in the spirit of palaetiology, I offer a linguistic example to show that the same principles apply once again. In the previous diagrams of Germanic language phylogeny (Figs. 6 and 7) the pattern of descent was entirely vertical, and it gave the impression that each language evolved independently and in isolation from its sister languages. From Figure 8, however, a diagram showing the history of selected Indo-European languages (Powell, 1988), we get a very different sense of the growth of Modern English. While there is indeed a line of transmission coming down from the early Germanic languages to Modern English, the ancestors of English are seen here to have received elements from a variety of sources, including Greek, Latin, and French. Does the fact that none of this linguistic borrowing is shown in Figure 7 mean that Figure 7 is false? Not at all: Figure 7 correctly depicts certain classes of events, while Figure 8 depicts many of the same events as well as some additional events. The relations among these diagrams are conceptually identical to relations that can be observed in cartography, for example between a map that shows a number of highways running in parallel, and another map that shows not only those highways but also a network of small roads that connect them.

One of the cartographic phenomena I mentioned above was feature displacement, a local warping of the scale that occurs when two objects are nudged closer together or farther apart in order to accomodate the desire of the map-maker to include a certain collection of map elements. When this is done to a limited extent it isn't noticed, but it can be concentrated for special humorous effect, as in the various entertaining maps that illustrate "A Bostonian's View of the World" or "A New Yorker's View of the World" (Gould and White, 1986). Is there a temporal equivalent of this warping of geographical space? There is, and it can be seen in at least two different palaetiological contexts. The first is in phylogenetic trees that stretch out around particular taxa, most often humans, and which thereby create "A Human's View of Evolutionary History" that is conceptually identical to maps showing "A Bostonian's View of the World" (O'Hara, 1992). A second palaetiological context in which the temporal equivalent of feature displacement can be seen appears in Figure 9, which reproduces a portion of a widely-used chart of geological time (Haq and Van Eysinga, 1987) on which the temporal scale changes repeatedly. The designers of this chart wanted to fit more temporal detail into the time scale in more recent periods, and to do so had to stretch out the temporal space. Once again, this process is conceptually identical to the warping of geographical space that we see in feature displacement, but it is carried here to an extreme that in cartography would be regarded as consciously humorous. It is worthwhile to consider how such warping of temporal space affects our sense, and particularly our students' senses, of evolutionary time and the history of the earth.

Let me close by suggesting a way in which this last question — the effect of conventional patterns of temporal generalization on students' perceptions of evolutionary history — might be addressed. Geographers have done quite a bit

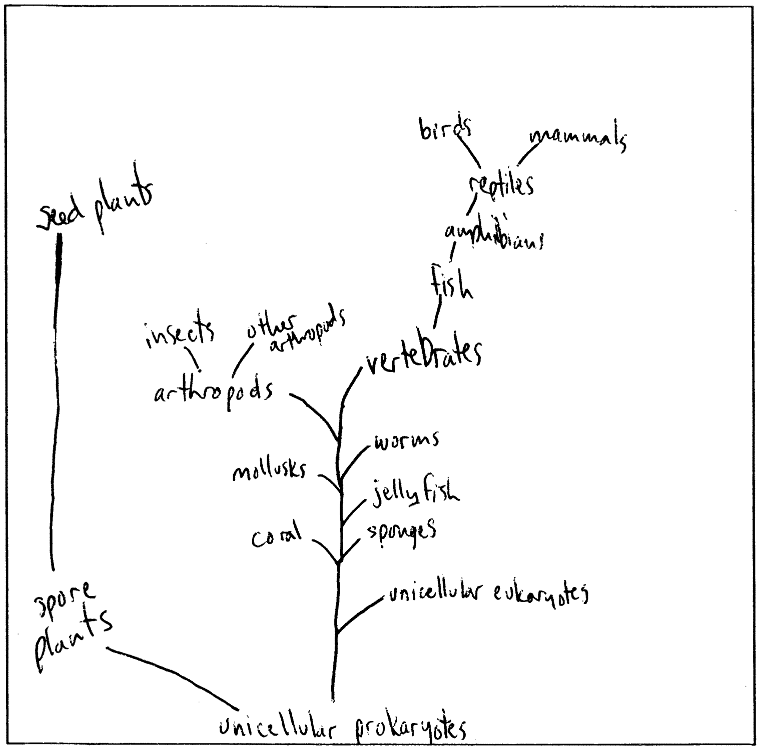

FIGURE 10. An evolutionary tree drawn by an undergraduate biology student at the University of Wisconsin. On the first day of a course on evolution each student was given a sheet of paper and was instructed to "sketch an evolutionary tree of life, and label as many branches as you can. Don't worry if your tree is not perfect, or if you can't remember technical terminology; this is not a graded exercise, and you should not even put your name on the page." Exercises such as this, which are modelled on geographers' studies of "mental maps" (Gould and White, 1986; Saarinen, 1988; Walmsley et al., 1990), may help evolutionary biologists to better understand popular conceptions of the history of life and to develop more effective teaching strategies.

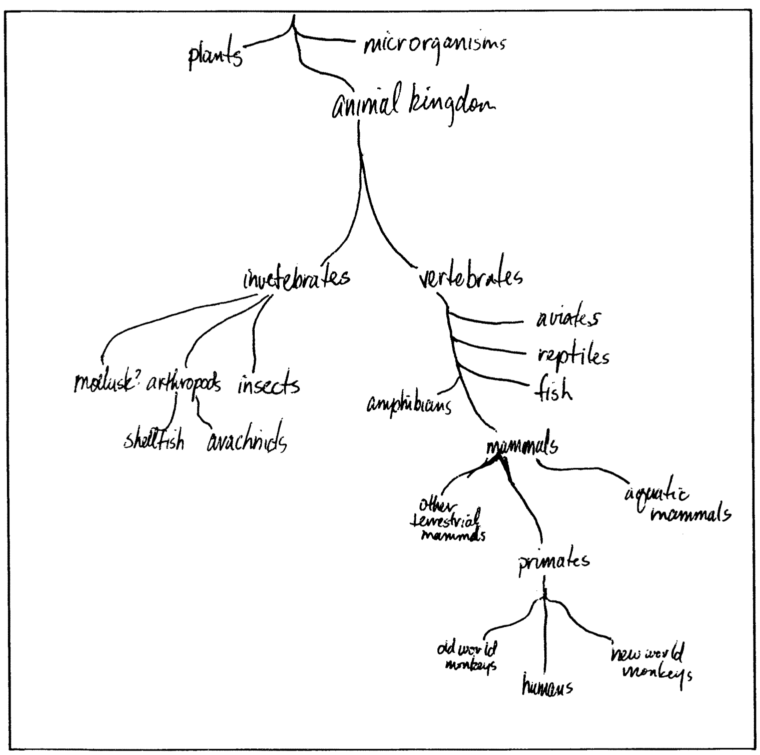

FIGURE 11. A second student-drawn evolutionary tree.

of research on what are called "mental maps" (Downs and Stea, 1973; Stevens and Coupe, 1978; Gould and White, 1986; Saarinen, 1988; Walmsley et al., 1990). If we take any person and ask him to draw from memory a map of his hometown, or of the world, or of any other region, the resulting map will reveal a great deal about that person's knowledge of geography, his perception of the sizes and distances between various geographical objects, and so on. Is it possible to do this same sort of research with historical representations? It is, and I offer here two sample results (Figs. 10 and 11) from a preliminary inquiry of this type, carried out with the assistance of Gregory Mayer at the University of Wisconsin. Students in a large undergraduate course on evolution were asked on the first day of class to draw an evolutionary tree of life as best they could, based on whatever knowledge they may have acquired from general reading or from other courses they may have taken. A great variety of images were produced by the students in this exercise. Many of them have a decided axis that leads to human beings, suggesting that there is still a widespread belief that evolutionary history is progressive or directed (O'Hara, 1992). A number of the diagrams clearly reflect the "five kingdom" arrangement of Margulis and Schwartz (1988), something that many of the students appear to have been taught in secondary school. Very few of the diagrams would be regarded by a contemporary systematist as particularly accurate. I hope to extend this preliminary study to other groups of students at other institutions in the future, and thereby build up a general picture of undergraduate understanding of evolutionary history.

William Whewell, with whom I began this essay, was not only an historian, a philosopher, and a scientist, he was also an educator: he served for many years as Master of Trinity College in Cambridge, and wrote university textbooks as well as essays on the importance of liberal education. Whewell believed that the palaetiological sciences — the historical sciences — were particularly well-suited for inclusion in a general liberal curriculum because they exemplify not only rigorous forms of thought and argument, but also the enormous reach of human reason by taking us farther back in time than previous generations of scholars would have ever thought possible. I think Whewell was right. I also think that by strengthening the ties that bind together all the historical sciences — all the disciplines that try to map the space of time — we will in turn strengthen our own particular special fields, and will be able to do a better job of explaining ourselves to our colleagues and our students in the future.

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