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Essay Review

Visualizing the order of nature

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Trees of life: A visual history of evolution. Theodore W. Pietsch. The Johns Hopkins University Press, Baltimore (2012). pp. 358, Price $58.99, Hardcover, ISBN-13: 978-1-4214-0479-0.

In 1837 Charles Darwin started experimenting with diagrams to capture his ideas about the origin and transformation of species. These diagrams, which were unpublished in Darwin's time (and some of them stayed unpublished until very recently (Voss, 2010)), were variations on a single theme: branching and rebranching to represent the appearance, divergence and extinction of species. He later publicly christened this genealogical pattern the great 'Tree of Life'; its visual counterpart has since become today's best known icon of evolution.

Darwin discussed and defended the tree 'simile' in a famous passage in the *Origin of Species* (1859):

> The affinities of all the beings of the same class have sometimes been represented by a great tree. I believe this simile largely speaks the truth…As buds give rise by growth to fresh buds, and these, if vigorous, branch out and overtop on all a feebler branch, so by generation I believe it has been with the Tree of Life, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever branching and beautiful ramifications (p. 129).

In *Trees of Life*, the Seattle fish and fisheries expert Theodore Pietsch offers a fascinating journey through the visual history of Darwin's image and, relatedly, one of the most fundamental problems in biology: the search for the natural affinities amongst living beings. Although not the first work to explore the imagery around this problem (Barsanti, 1992; Nelson & Platnick, 1981; O'Hara, 1988, 1991; Papavero & Llorente, 1993–2004; Ragan, 2009; Rieppel, 2010; Stevens, 1994), Pietsch's book constitutes a most useful resource to historians and anyone interested in scientific representations.[1] Engagingly written and illustrated, it provides fascinating historical information that bolsters understanding and curiosity about five topics in particular: how the notions of taxonomy and classification have changed through time; the pre-Darwinian use of trees; when and how the 'Tree of Life', originally inherent to biblical Paradise, became an object of scientific enquiry and subject of theoretical examination; the importance of images for the construction, acceptance and dissemination of knowledge; and the promising future of systematics, which already intersects in the study of life's diversity with molecules, fossils and whole organisms.

As is well known, during Darwin's time, naturalists were engaged in the problem of achieving natural classifications of living beings, reflecting their place within the order of life. This search for the 'natural order' can be traced back to ancient times. In Europe, especially from the sixteenth century, an astonishing imagery sprung up around this enterprise, reflecting the depth of attention naturalists gave to it. Not just trees but many objects served as metaphors for order in the world. We can order them into three main epistemological categories: series, trees and networks (Barsanti, 1992; Ragan, 2009; Rieppel, 2010), each reflecting a particular conception of species and theories underlying the foundation of the natural system. Series are the oldest metaphors, followed by networks. Series represent a linear and hierarchical order of nature, in the form of chains, cords, ladders and stairways. They reflect the conception of fixity and immutability of species proper to the plan of creation. By the mid eighteenth century, series decreased in popularity as the previously significant 'great chain of being' was increasingly viewed as an inadequate description of the natural order (Ragan, 2009). An alternative metaphor for the order of nature that flourished in the late eighteenth and very early nineteenth century was the network of affinities, which, according to Müller-Wille, Linnaeus expressed in the metaphor of a map-like structure with mutual affinities going in all directions" (Müller-Wille, 2007, p. X, in Rieppel, 2010). The metaphor of a branching tree was also born in this era, along with a variety of geometric diagrams that reflect the creativity of naturalists worried about finding the natural order.

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[1] It is worth mentioning the contribution made to the history of systematics by Jorge Llorente and Nelson Papavero. They published between 1993 and 2004 an impressive collection of nine volumes called *Principia taxonomica*. The spirit of these compendia is catholic. It begins with the very first attempts to classify organisms and ends with the development of systematic phylogenetics as a way to achieve classifications of sets of organisms based in their evolutionary relationships.

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In his first seven chapters, Pietsch gives an idea of the intense efforts of naturalists to classify and identify groups in the natural system, as well as their struggle to visualize it. Prior to the eighteenth century, it wasn't at all obvious that a tree is the best candidate for representing the order of nature (Hellström, 2012; Nelson & Platnick, 1981, p. X). To appreciate fully the differences between early brackets and tables from the sixteenth and seventeenth centuries, and the more sophisticated diagrams that appeared later, it is important to differentiate between the classification issue, which flourished especially from the sixteenth century, and the identification and placement of natural groups in the natural system. Both techniques for the identification of species belong to the realm of taxonomy, but the first tries to name species according to keys in an 'artificial system' (brackets and tables), while the second calls for the creation of a diagram that reflects the laws underlying the true order found in nature (O'Hara, 1996). Thus brackets, or what some scholars refer to as 'dichotomous' tree diagrams,[2] were not used to represent affinities, but rather dichotomous analytical keys, based on alternate states of a key character (Stevens, 1994, p. 170, in Rieppel, 2010).

Curiously enough, Charles Bonnet, in 1764, was first to propose a reticulated alternative to the *scala naturae* in botanical terms. It is curious because he is considered "the most important eighteenth century advocate of the Great Chain of Being" (Rieppel, 2010). However, he too had to face the problems posed by the effort to sort organisms' attributes into an unbroken ladder of life;

> Does the scale of nature become branched as it arises? Are the insects and mollusks two parallel and lateral branches of this great trunk? Do the Crayfish and the crab likewise branch off from the mollusks? We still cannot answer these questions.[3]

In fact, metaphors for the order of nature distinct from the series (reticulated systems such as networks, webs, branching diagrams and tree-like figures) resulted from the struggle of naturalists to 'fit' some of the organisms' traits in a consistent gradation of forms and into a linear sequence, whether given by the idea of a Chain of Being or by the Linnean system of classification.

There are several examples of the naturalists' confusion when trying to arrange their objects of study in a defined linear order. In his *Della storia naturale marina dell'Adriatico of* 1750, Vitaliano Donati argues that "when I look at Nature's productions, I do not see a single, simple progression or chain of beings, but a large number of uniform, perpetual and constant progressions...that should be compared more to a *network* than to a chain..." (Donati, 1750. Italics added for emphasis). The renowned French naturalist Georges Cuvier had abandoned the idea that animals could be organized in a series, and the famous French botanist Adrien de Jussieu mentioned in 1843 that "relations between groups must be definitely cross-linked; it is impossible to form linear series because emphasizing a relationship in one direction necessarily involves breaking it in another" (de Jussieu, 1843).

Authors drawing or referring to the idea of a tree-like branching diagram are presented in the 'pre-evolutionary section' of *Trees of Life*. Peter Simon Pallas (1766), Georges Louis Leclerc de Buffon (1766), Augustin Augier (1801), Count Jean Baptiste de Lamarck (1809), Nicholas Charles Seringe (1815), among others used the image of a tree as an organizing principle in natural history. Nonetheless, by Darwin's time no one had shown what kind of affinities were necessary to achieve a natural system (except for Lamarck) and it was not at all clear what sort of diagram was best suited to represent natural affinities. During the eighteenth and the first half of the nineteenth centuries, sweeping geometries such as circles, stars and maps started to flourish.

Today we credit Darwin for having finally solved the problem, if not methodologically, at least theoretically. In 1859, by a single branching diagram, Darwin was able to resolve several epistemological problems of nineteenth century biology. He showed that genealogy of species was the kind of affinity that naturalists were seeking in order to achieve the construction of a natural grouping of species—a natural system[4]. He provided the possibility of linking the consistency between genera and species and their ability to change—which is the necessary condition for their evolution (Weigel, 2007), and provided a real cause, an explanation based on historical evidence, of the origin of diversity by means of the accumulation of insignificant changes over vast amounts of time (see Gould, 2002). Importantly, Darwin also combined isolation and divergence (natural selection) with independence of species.

In a letter to John Murray, his publisher, Darwin—aware that his tree image was unorthodox—explains that "the diagram...is an odd looking affair, but is *indispensable* to show the nature of the very complex affinities of past & present animals" (Darwin, 1859). To many, Darwin's odd looking diagram is the materialization of his 'Tree of Life' metaphor, thus a tree itself. As Darwin predicted that taxonomies would become "as far as they can be so made, genealogies" (Darwin, 1859, p. 486), in the following decades many scholars around the world started proposing branching diagrams to represent the evolution of lineages, and 'trees of life' proliferated from the late nineteenth century on.

The 'Tree of Life' in the life sciences is a contemporary concept and today it is possible to identify two different uses for the term. During late nineteenth and early twentieth centuries the term 'Tree of Life' was employed for representations of the genealogy of species. But it was mainly after Ernst Haeckel's 1874 image of a twisted European oak to represent the 'family tree of man' (Stammbaum des Menschen), that the image of a real, botanical tree became an object of energetic scrutiny and cultural significance. Although Haeckel's 'Stammbaum des Menschen' was not named or referred to in the text as a 'Tree of Life'—as it was intended to depict the 'ascent' of man—posterior scientific illustrators did when depicting not only man but the evolution of life. However, from the early Twentieth century, this 'Haeckelian style' of visualizing evolutionary relationships by means of literal trees found its way, not to the scientific thinking about evolutionary relationships, but to the public domain. Two reasons come quickly to mind. The first is the implicit difficulty of achieving a truly universal Tree of Life. The second is that Haeckel's 'family tree of man' was assumed to represent an upward journey of life from the most primitive beings at the bottom to the most advanced at the top. Scientists quickly sought to distance themselves from the implications attached to Haeckel-like trees and, in general, they stuck to strict line-diagrams in the Darwinian fashion. Thus, scientific 'trees' of evolution—though promoting branching as a primary icon for the history of life—were abstract, lines of descent to represent plausible hypothesis. An interesting example is that of Henry Fairfield Osborn's trees. Osborn was among the first to create human evolutionary trees for general audiences in the United States. His trees intended for scholars pictorially differ from those addressed to popular audiences. The first are line-diagrams and the second are real, botanical trees (e.g. Osborn's 'Ancestral tree of anthropoid

[2] "Keys are hierarchical arrangements intended to aid identification or information retrieval, and are sometimes presented as a branching logical structure, *i.e*. a tree" (Ragan, 2009).

[3] Bonnet, 1764:59, in Pietsch (2012, pp. 1–2).

[4] It is important to mention that Darwin never differentiated the concepts of genealogy and phylogeny with its diverse components. However, implicitly genealogy is the core of phylogeny.