Knowledge Uprooted[1]

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ABSTRACT

In the first millennium, western thinkers saw knowledge the same way they saw the rest of the world: ordered. Concepts and the entities they stood for fit in a neat cosmos, structured as a tree whose root was generally divine, and whose trunk and branching limbs represented the hierarchy of knowledge. Over the last thousand years, that arboreal vision has slowly been replaced by a more diffuse one, web-like and de-centered. The visual metaphors and ontology of knowledge have co-evolved, feeding off one another and co-creating a new order of rhizomatic ideas that stretches from classification theorists to practicing scientists and the general public. The Christian hegemonic tree has been replaced, fittingly in the age of the internet, by a great web. Such an ontological shift is having epistemological repercussions, and will likely continue to affect how the modern world thinks about thinking.

INTRODUCTION

The words for learning or knowledge in the Germanic languages have an interesting root. English words like 'wits' and 'wizard' and German words like 'wissenschaft' come from the old Germanic/Norse 'wid(?)', meaning 'wood' or 'forest' or 'tree' (Lima 2011, ??). The ancient relationship between trees and knowledge is not merely visual; rather, knowledge in its very essence knowledge has had a close relationship to trees for thousands of years. Countless cultural and religious traditions associate knowledge with trees, not least of which in the Bible, where there fruit of one tree is knowledge itself.

During the Roman Empire and the Middle Ages, the sturdy metaphor of trees provided a sense of lineage and order to the world that matched well with the neatly-structured cosmos of the time. Common figures

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of speech we use today, like "the *root* of the problem" or "*branches* of knowledge" betray the strength with which we have connected the two concepts.

As with any study of such a long duration, the words used to describe the concepts they discuss have changed in meaning many times, and a few of those changes need mentioning. We presently think of knowledge about a subject as separate from the subject itself, and both are separate from the worldly manifestations of that subject. Our knowledge of physics, for example, is largely social and contingent, whereas the laws of physics themselves are fairly universal, though subject to shifts in perspective; balls rolling down inclined planes are simply events that happen and then stop. During the earlier periods of the forthcoming narrative, there was less of a clear distinction between these concepts. If physics were a branch of a tree from which sprouted electromagnetism and gravitation, that hierarchy could encompass knowledge, subject, and entity.

Genealogy was also an important concept for these trees. Family trees, with branches representing family lineage, trace back at least to the 1st century B.C.E. (Franklin 1999, ??). Using the same arboreal metaphor for knowledge often implied that the hierarchy was also historical; God at the root of a tree from which branched physics and ethics and medicine could also imply genealogical precedent. To confound matters even further, trees were a vehicle to transmit the widespread use of medieval dichotomies; thus they could be used to represent either a separation into constituent parts, or the opposition of related concepts. It is often unclear precisely how these trees were to be interpreted, and future generations looking back on them might transition between such concepts quite easily.

'Knowledge' as well is simply a shorthand for a conglomeration of concepts which changed over the centuries. In the earlier periods, it is difficult to separate the order of *knowledge of* subjects from the order of *subjects and things themselves*. Philosophy might be connected to ethics, God, mechanics, logical fallacies, books, or types of fortifications all in the same tree. Later uses of knowledge might be closer to academic disciplines, or the subject of study of those academic disciplines. I opt to use 'knowledge' over 'science' or 'natural philosophy' simply because it has slightly less current scholarly baggage, not because it is any more appropriate to all time periods.

As words and concepts changed over the years, so too did the structures of knowledge themselves. Trees were often added to and changed, with certain tropes remaining fairly constant over more than a thousand years. The metaphors were initially used by philosophers, educators, and theologians. As the trees grew, so did their complexity, and by the Early Modern period they had become diverse and occasionally lost their single root. Natural philosophers used them to justify their worldviews and organize their endeavors. By the Enlightenment, the trees were so hopelessly tangled and poorly weighted that they eventually collapsed under their own weight, and encyclopedists claimed they should be dispensed of entirely. Notably, these claims did not lead to the end of trees, even in the encyclopedias themselves. It took classification theorists of the late 19th and early 20th centuries to finally decide once and for all that a single-rooted tree was inadequate for representing knowledge, offering a multitude of metaphors to take its place. None stuck.

The careful cosmos of ancient knowledge had been replaced by a chaos of disciplines. Modern discussions of interdisciplinarity require a sense of individualized disciplines with no central structure, and indeed both disciplines and interdisciplines arrived at the same time, co-dependent upon another (Abbott 2001, 132). A combination of late-20th century philosophers, bibliometricians, and the growing popularity of network science eventually led to the use of rhizomes (Deleuze and Guattari 1987) and networks as the primary metaphors of knowledge orders. Across this vast span of time, the concept of a unity of knowledge played a major role, with knowledge's eventual disunity inspiring a break from the tree metaphor. Oddly, the network metaphor used to replace it is once again one of unity and consilience (Wilson 1998).

This is a history of changing ontologies and visualizations of knowledge. It begins with a biblical tree and ends at the World Wide Web, starting with single roots and concrete hierarchies, continuing through a period of hierarchical separation into many roots and many trees, and ending with the recombination of a multitude of trees into a diffuse web of ideas. The shift was neither inevitable nor universal, but it was noteworthy.

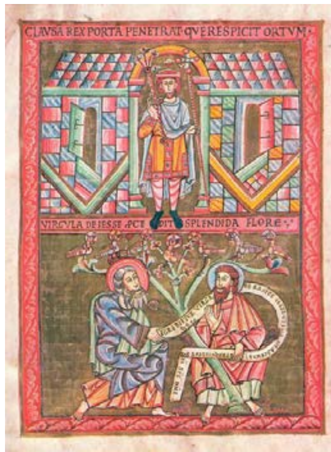
ONTOLOGY AND EPISTEMOLOGY

The two thousand or so years of slow movement from linear hierarchies to diffuse webs in popular visual representations of knowledge have some important repercussions. In Daston and Galison's various works on Objectivity and Visualization (Daston and Galison 1992; Daston and Galison 2007; Daston 2008), they note several ways in which visualizations actually create what scientists eventually consider to be objective units of study. They discuss early 20th century scientist Ludwik Fleck, who when discussing microscopic observations of bacteria, noted that novices see only blobs when looking under the microscope, whereas with training, the expert finally discerns bacteria. With that training, however, the expert loses the ability to see anything that contradicts the form that she knows to be visible. Perception training shapes and sorts the universe, outlining edges and arranging parts into wholes. As Daston (2008) writes, "perception furnishes the universe. It doesn't create the universe, but it does shape and sort, outlining sharp edges and arranging parts into wholes." Scientific perception of objects is a deeply psychological affair.

Collective and continuous observations create scientific objects, such that eventually the chaos of ever-changing clouds in the sky can eventually be dissected and classified to the various forms we know today (cirrostratus, cumulonimbus, etc.). An important step in the creation of these scientific objects is the act of illustration, which distills and unifies many observations into their defining characteristics, as with the cloud atlases of the late nineteenth century. This is true not only of bacteria under microscopes, or types of clouds in the sky, but also more abstract visualizations like charts or graphs. The way we distill knowledge visually deeply influences how we understand the shape of that knowledge. Visualizations, essentially, create scientific objects and the relationships between them. While a visual language works toward solidifying scientific objects, communities of practice gather around and are defined by their use of those visualized objects (Rudwick 1976). The nature of those scientific objects then shape the path and the epistemic values of that scientific community in subtle but powerful ways (Huber 2011). By visualizing knowledge itself as a tree, our ancestors reinforced a certain epistemology and ontology of knowledge, ensuring that we would think of concepts as part of hierarchies and genealogies for hundreds of years. As we slowly moved away from strictly tree-based representations of knowledge in the last century, we have also moved away from the sense that knowledge forms an absolute hierarchy. Instead, we now believe it to be a diffuse system of occasionally interconnected parts.

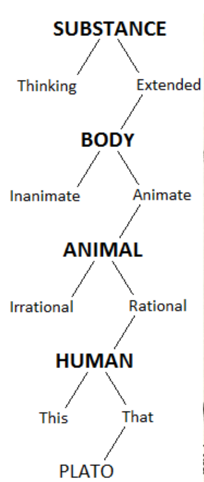
FROM TREES TO WEBS

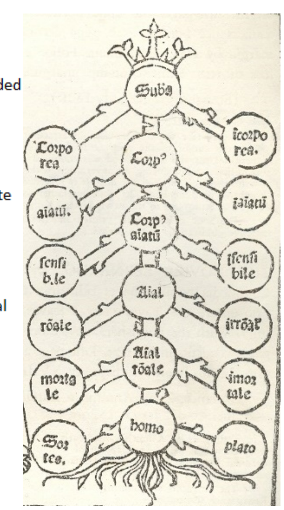
The tree as a visual metaphor used to abstract is at least as old as ancient Rome, according to Seneca and Pliny, who both described family trees hanging on the walls of Roman homes (Franklin 1999, ??). The biblical importance of two trees in particular, one of life and one of the knowledge of good and evil, ensured that trees would remain important symbols in the Judeo-Christian Greco-Roman world. Christian tradition also invokes the 'Jesse Tree', a genealogy tracing Christ back to King David.



The first thousand years C.E. saw a flourishing of metaphorical illustrations of knowledge, only some of which were tree-like. Still, over that time trees had reached phenomenal popularity (Murdoch 1984, ??), and by the 12th century, they had achieved widespread legibility as a visual metaphor to connect hierarchies, lineages, and orders (Klapisch-Zuber 2007, 294). Trees fit well with the western intellectual traditions of dichotomies and an ordered cosmos, with a place for every entity and concept, where thought was a process of division and recombination. The written metaphor of a tree, with a central root and trunk to hold together abstract ideas, was used to describe knowledge at least as early as the 3rd century C.E, in Porphyry's treatise on Aristotle's *Categories*. He describes the Aristotelian system of categories into a series of branching dichotomies, and describes them as a tree.

By the 6th century, a Latin translation by Boethius illustrated Porphyry's metaphorical tree as a visual one. The tree separates 'Substance' into that which is thinking, and that which is extended. Branching off from extended substance is 'Body', which itself branches into animate or animate. The tree continues branching until it defines the place of individual humans, like Plato or Socrates, in the grand classification of categories. Illustrations of Porphyry's tree show a visible trunk on which families of things reside, and then uses those branches to represent dichotomies within each family. [Need citation]

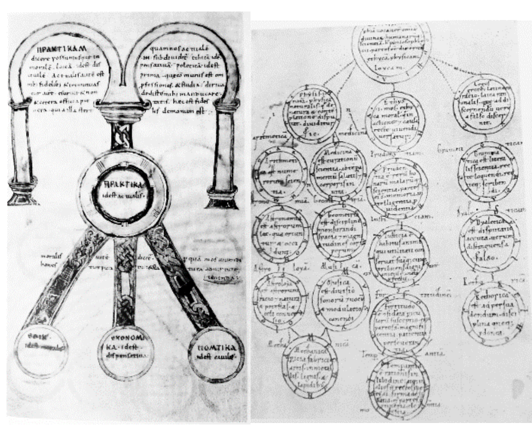




This 3rd century tree, and 6th century illustration, would be visually repeated and added to for over a thousand years and forms the historical basis of tree diagrams of knowledge. At this point, knowledge of a subject and the subject itself were not yet separated. This tree performed the triple task of representing things, concepts of those things, and awareness of those concepts.

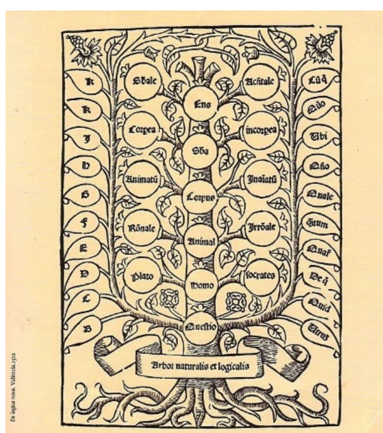
Indeed, though often diverging, Aristotelian and Platonic philosophy shared a few key elements which were integral to the creation and interpretation of diagrams of knowledge. For them, thinking was a form of seeing, and all concepts were attached to visual objects, whether internal or external. The visual was the connection between thought and the world, and this led to a philosophical system where it was difficult or unnecessary to separate concept and thing (Robinson 1972, 23). This interweaving found its way into Christian thought through Saint Augustine (and even Boethius) in the 4th-6th centuries, and would not be seriously disputed until Thomas Aquinas separated the order of being from the order of knowledge in the 13th century (*ibid.*, 45). Aquinas' example was simply only one of a few counterexamples, however; few before or for quite some time after thought it necessary to distinguish ontology from epistemology. What resulted was a history of transcendent visualizations which ordered both the mind and the world it observed.

At this point, however, there was not yet a standard metaphor for visualizing knowledge. Trees were only one of many varieties of diagrams used, and although nearly all such diagrams featured knowledge as branching or hierarchical, the illustrations themselves took many forms. An 11th century manuscript on grammar, for example, depicts knowledge a bit like a hub connected to spokes. It separated practical knowledge into ethics, economics, and politics. A 12th century manuscript illustration begins with a central circle for philosophy and separates that concept out into natural, ethical, and rational knowledge. Rational knowledge separates into grammar, dialectic, and rhetoric, and the other branches divide into their own constituent parts from there. Many other illustrations have been found around this time period with similar features, focusing on overarching concepts and their dichotomies. Non-hierarchical concept maps were rare or absent entirely (Murdoch 1984).

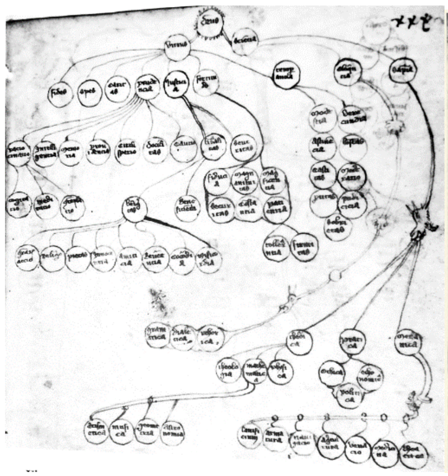


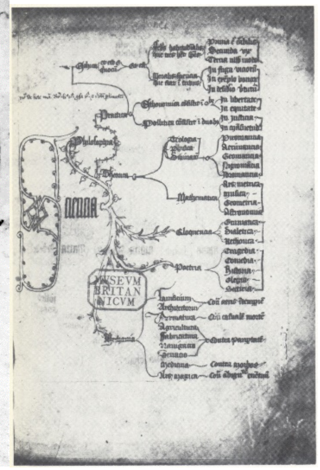
There was a fourth use to these diagrams, beyond representing genealogy, ontology, and organization: pedagogy. The seven liberal arts separated into the Trivium, consisting of grammar, rhetoric, and logic (an extension of what was represented in Figure 3(b)), and the Quadrivium, consisting of arithmetic, geometry, music, and astronomy. This was the medieval curriculum, and like before, it separated knowledge for the purpose of education *exactly as knowledge ought to be separated*. This was the true order of things, and was taught as such. [Need citation]

The poet, mystic, and philosopher, and Christian Ramon Llull is an extremely influential figure in this story. His late 13th century *Arbor Scientiae* is likely the first work that attempted to systematically represent all branches of knowledge on trees. The book features 16 illustrations [check this], the first of which is a single tree with all the knowledge, used as a sort of table of contents, and the following trees each representing a single branch from the first tree. Trees represented branches like physics or ethics or biology, and the book would influence thinkers like Bacon and Descartes. More than anything, however, Llull's mark was left in his pursuit of a unity of knowledge and a systematic classification of the cosmos and the knowledge about it. [Citations needed] This unification occurred under a system where being and knowledge were governed by the same mathematical laws, and patterns in one matched precisely to patterns in the other (Robinson 1972, 49).

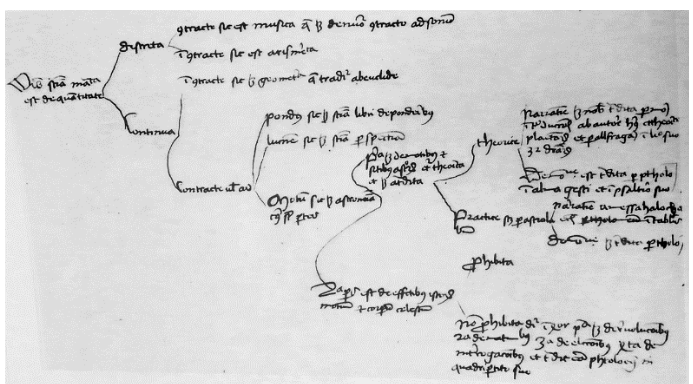


Because of the intrinsic hierarchical nature of these trees, what sat at the root was of absolute importance. God at the root implied divine primacy which was, by this time, a common feature of knowledge representations. A single 14th century manuscript (Murdoch 1984) contains two illustrations which diagram knowledge as a series of branching spheres. The two illustrations are themselves dichotomies of one another; the first featured God as the root of the hierarchy; the second gave that status to the devil. Within the divisions of the divine tree, versions of Aristotle's categories and the liberal arts have their place, as do other dichotomies, whereas the sinister tree features the likes of sins and logical fallacies [Check if this is true]. Another 14th century manuscript (Murdoch 1984) features an illustration of a very naturally-inspired tree, full of leaves and twigs, which represents Aristotelian logic. A feature worth noting in both of these trees is the frequent use of repetition and annexation. Many of these trees were simply more encompassing versions of earlier ones.

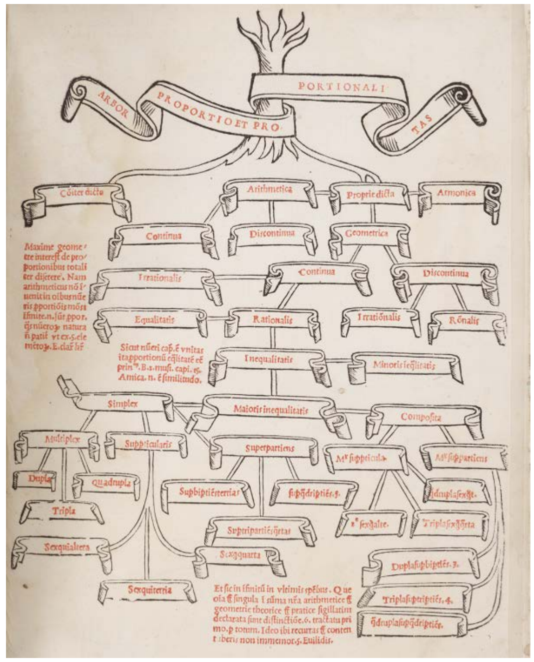




Trees were even being used by students themselves as study aids (Murdoch 1984). One 15th century diagram began with the root of overall mathematical knowledge, dividing it into those which cover the discrete, and those which cover the continuous. Continuous knowledge branched into geometry, weight, light, or motion, and then divided further from there. What's notable in this case us that, under each branch, the student listed relevant reference material, as with Euclid's *Elements* under geometry [check if this is true]. This was likely done as a way to organize and remember important books.

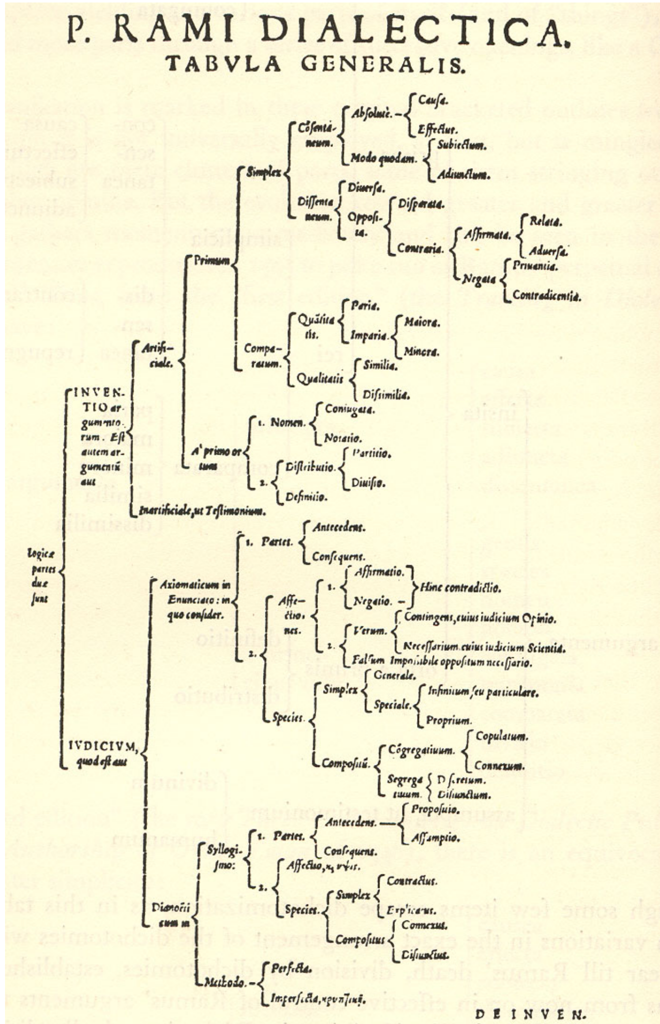


One example of the growing sense of an infinite subdividing of the cosmos into parts can be found in Pacioli's 15th century *Summa de Arithmetica*, which contained a 'tree of proportions' illustrating the varieties of mathematical proportions (Franklin 1999). It includes the now-common mathematical dichotomies: continuous and discontinuous, arithmetic and geometric, rational and irrational. The scribe adds the note, however, that had he finished the diagram, it would continue indefinitely off the page. Also worth noting here, though it has also been present in previously highlighted illustrations, is that the dichotomy is almost fractal in nature. Both geometry and arithmetic break into continuous and discontinuous; those categories both break into rational and irrational, and so forth. This is a succinct microcosm of the ordered cosmos: infinite complexity that is finely structured, but with a single root and repetition at every scale.

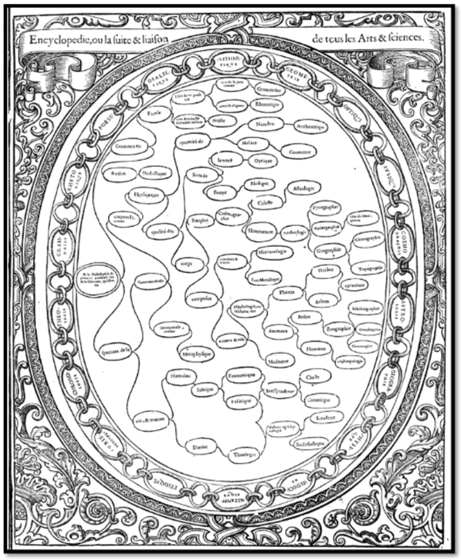


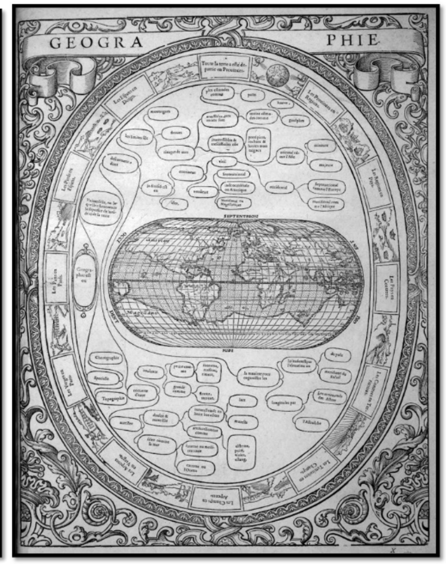
By this time, it is clear that when concepts were illustrated, they were put in trees and similar hierarchies. These featured a single root from which all knowledge branched, usually some ancient knowledge category or, ultimately, God. It is no coincidence that that the other oft-used tree illustration, family lineages, also often traced back to some religious root [mention Sephardic trees here as well]. Trees allowed one to put everything in its proper cosmological place, and by the end of the middle ages, these diagrams were common and standardized enough to be decipherable across Europe (Kruja et al. 2002; Klapisch-Zuber 2007).

Petrus Ramus was a transitional figure in the 16th century, an influential educational reformer who both embodied and perfected the old fascination with dichotomies, but also attempted to break with the particular structures often invoked with their origin in Aristotelian thought. Ramus, instead, hoped to re-systematize knowledge according to new and more appropriate dichotomies. His diagrams were so influential that all such diagrams, including the Porphyrian tree and other famous historical ones listed here, came to be known as *Ramean trees*. A remarkable example of the paradox that was Petrus Ramus, however, was his insistence that disciplinary knowledge should fit on a unified circle, rather than in a hierarchy: an all-connected unity of knowledge. Not only does Ramus represent a break from hierarchy, but also from genealogy. In his system, there was no longer the appeal to ancient and authoritative works that so imbued the sense of a historical origin of knowledge in previous systems (Kelley 1981; Ong 2005). While he broke from genealogy, however, his system did not separate essence from knowledge. His orders weren't merely instructive, they were *true*. According to Robinson (1972, 91), for Ramus "the floor plan of the cosmos is neatly contained in the orderly places of the human mind." There is no place for subjectivity here; were multiple people attempt to diagram the space of knowledge, they would inescapably arrive at the same shape.

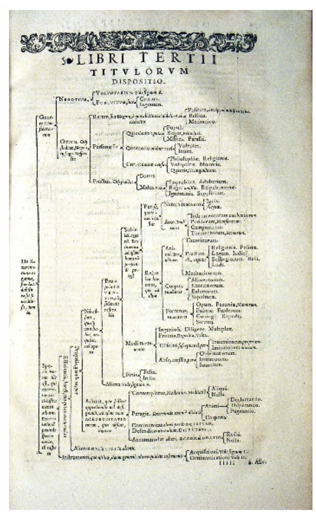


Inspired by Ramus, Christophe de Savigny, published in 1587 his *Complete Table of All Liberal Arts*. Reminiscent of Llull's masterpiece, Savigny's features an introductory illustration depicting the branching of all knowledge in a single-rooted hierarchy beginning with philosophy of the liberal arts, and branching into the special or the general. Ramus' influence is apparent, however, as the entire hierarchy is surrounded by a circular chain of knowledge, a metaphor used by Ramus himself. This first illustration is a sort of table-of-contents, followed by sixteen more diagrams further subdividing the specific branches of knowledge. Opposite each page, Savigny wrote an encyclopedic description of the topic at hand, including grammar, rhetoric, geometry, medicine, and law [citation needed].

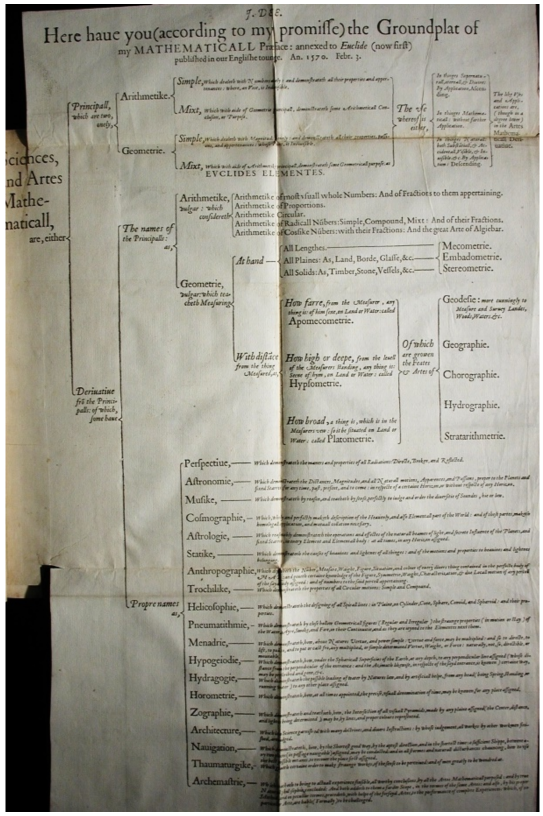




The use of these diagrams as a preface and organization to encyclopedic texts was becoming increasingly common. Gregor Reisch's *Margarita Philosophica* was one early example, in the beginning of the 16th century, which rooted knowledge in philosophy and broke, like Savigny's later example, into the specific and the general, further subdividing as necessary. Theoder Zwinger's encyclopedia, *Theatrum Humane Vitae*, also includes a tree diagram to organize his monumental work, and similarly begins with the general/specific dichotomy. In short, the structure of knowledge had become fairly standardized [citations needed].

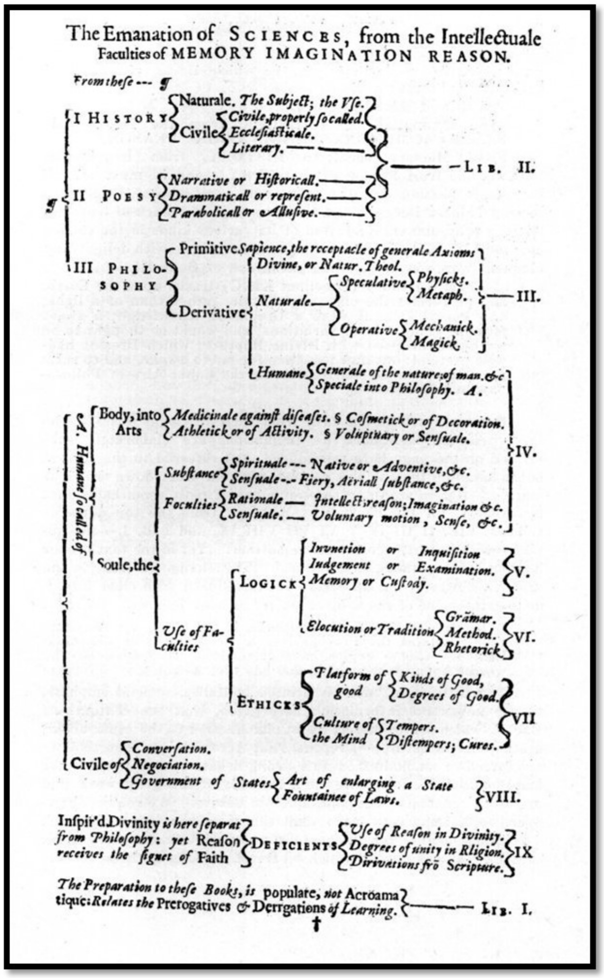


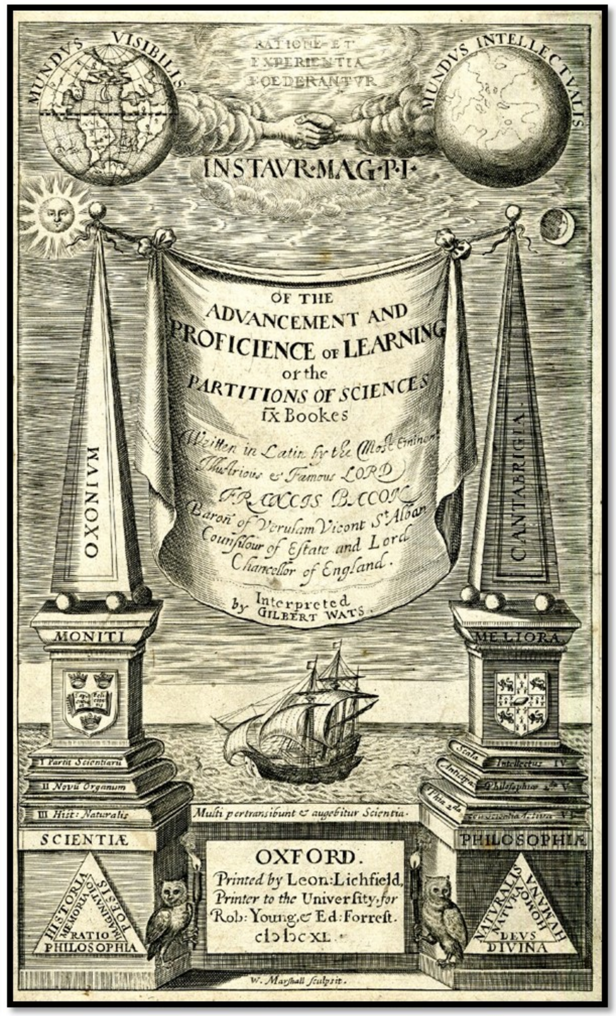
A close connection of Ramus, John Dee, wrote one of the most important early defenses of mathematics in English, in the form of a preface to Euclid's *Elements*. At the end of the preface, he lays out a diagram inspired by Ramus that includes the branches of all human knowledge. The 'groundplat', as he calls it, should be a pedagogical aid; more than that, though, this illustration depicts the true structure of the arts and sciences. The term connects 'plot', meaning a visual structure connecting ideas, with 'ground', meaning a logical foundation, resulting in a diagram of the logical essence of conceptual relationships. It, like so many earlier trees, is a transcendent and true ontology of knowledge (Robinson 1972, 123-126).



If the tree metaphor was ever in doubt, certainty can be found in the great works we often associate with early modern science. Dee's 1582 preface to Euclid was no-doubt known to Francis Bacon, who wrote *The Advancement of Learning* in 1605 [citation needed]. The subtitle of the book was *on the partitions of the sciences*. Bacon wrote "the distributions and partitions of knowledge are […] like branches of a tree that meet in a stem, which hath a dimension and quantity of entireness and continuance, before it come to discontinue and break itself into arms and boughs." The highly influential book broke in three ways from its ontological predecessors: it broke the "one root" model of knowledge, it shifted the system from a closed to an open one, capable of growth and change, and it detached natural knowledge from divine wisdom.

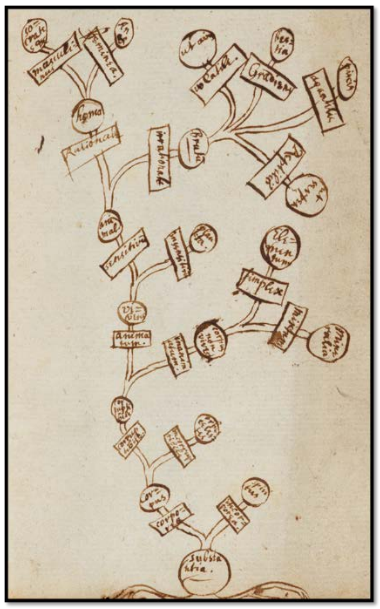
Bacon divides knowledge into history, poesy, and philosophy, each as separate entities with their own root. This was likely, in part, a successful rhetorical strategy to argue that natural philosophy should be explored at the expense of poesy and history. It separated out philosophy as a different kind of knowledge, worthier than the other two (Simpson 2005). Entwined in the new order of knowledge was the idea that learning could be *advanced*; that the whole of knowledge could not be represented as an already-grown tree, enclosed by Ramus and Savigny's circular chain of learning. Instead, the tree was exposed and open, capable of growing buds into new branches. There was no complete order of knowledge, because knowledge changes [citation needed]. Bacon's system of natural knowledge was no longer a whole and perfect entity, and was notably separated from divine wisdom (Klapisch-Zuber 2007).

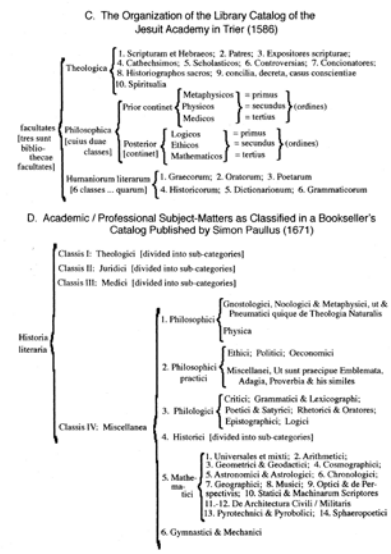


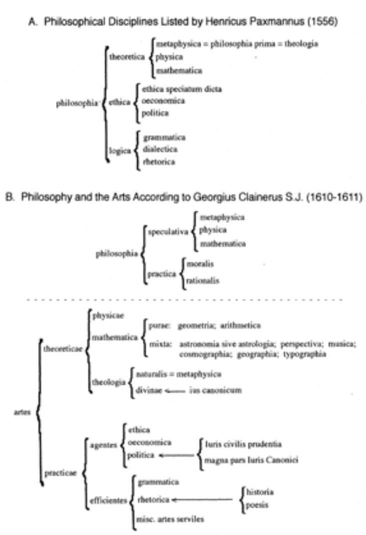


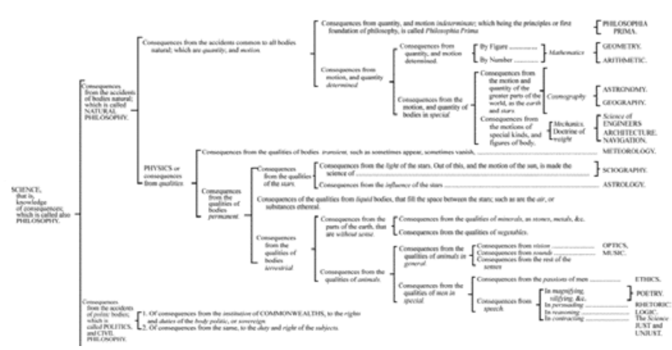
Descartes' seventeenth century *Principles of Philosophy* [citation needed], on the other hand, puts thought–particularly metaphysics–at the foundation of the tree of knowledge. For Descartes, thought and God went hand-in-hand, and the base of the tree also represented God's principle attributes (Ariew 1992). Descartes writes "Thus the whole of philosophy is like a tree. The roots are metaphysics, the trunk is physics, and the branches emerging from the trunk are all the other sciences, which may be reduced to three principal ones, namely medicine, mechanics and morals." Descartes' ordering is based upon disciplinary foundations, one into another, and how the objects of the various studies relate to one another. It again had only a single root, with the usual set of branches. That this tree-like thinking is so prevalent in Descartes is particularly remarkable given his dualistic mind/body philosophy. One would imagine that each of the primitives would be a trunk to a separate tree; instead, Descartes suggests medicine, a mind/body interaction, branches wholly from physics, a set of body/body interactions. Even as Descartes' philosophy suggested movement away from a unified hierarchical structure of knowledge, the historical prominence of trees rooted him to their use in the face of representations more appropriate to his thinking.

Even well into early modern Europe, arboreal symbolism deeply connected biblical and scientific knowledge. The myth of Newton's apple tree, his gateway to universal gravitation, is likely attributable to this connection (Epstein 1979). A 17th century poet, Abraham Cowley, wrote of the biblical tree (1656, 1881): “That right *Porphyrian Tree* [emphasis added] which did true Logick shew // Each Leaf did learned Notions give, // And th’ Apples were Demonstrative.” Newton plucked knowledge from the Porphyrian tree. This is not too far from the mark; the education system was littered with pedagogical tree structures, and a notebook from Newton’s undergraduate years revealed he, too, made use of them. Other contemporaries like Leibniz, Locke, Hobbes, Kant, Spinoza, Gassendi, and Mersenne also tried their hands at creating unified systems of knowledge (Flint 1904; Biener 2008). By this time, as well, these trees were being used frequently as organization schemes for libraries and booksellers’ catalogs all across Europe. [citation needed]

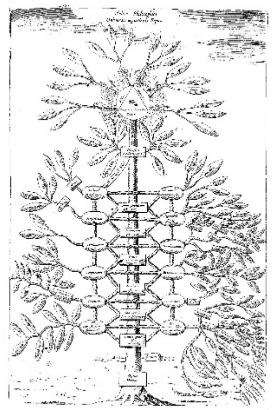






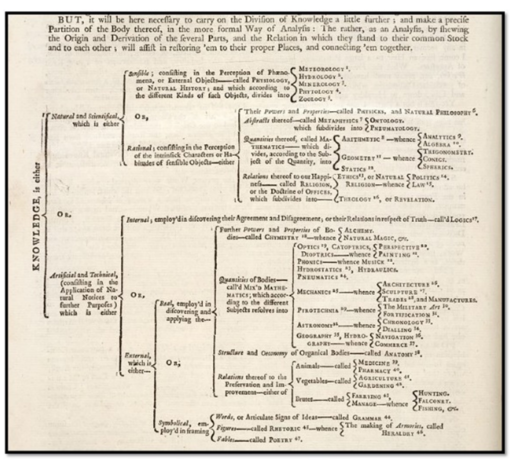


Athanasius Kircher’s tree of “the universe of types” of knowledge is another case in point. The center of his tree is a modification of the now-1,300-year-old Porphyrian tree, and he placed God on the tallest branch rather than at the root. Notable in this diagram is the sheer number of branches, with some areas quite dense and others very sparse. By the 17th century, these trees were already becoming nearly too complex to handle. [citation needed]



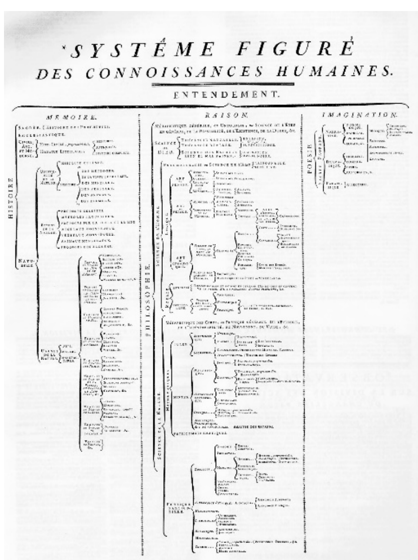
If the 15th, 16th and 17th centuries were the period of a simultaneous flourishing and questioning of the hegemonic tree of knowledge by educators and natural philosophers, the 18th, 19th, and early 20th centuries represented a movement away from these trees by enyclopedists and classification theorists. They had not yet decided what would replace the tree.

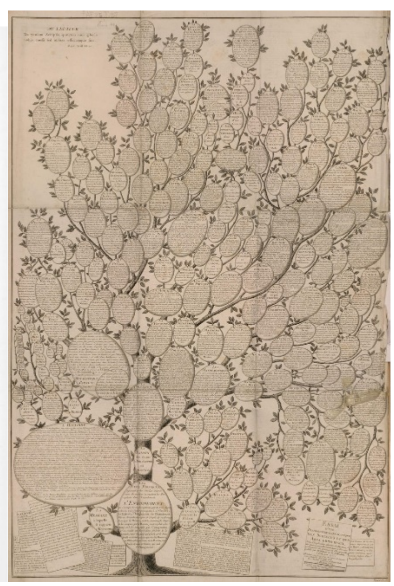
One of the first great large-scale encyclopedia projects, Ephraim Chambers' 1728 *Cyclopædia* would become an inspiration to future works. Although its forty-seven divisions of knowledge were organized alphabetically, Chambers used a tree to show the hierarchy of that order. He also employed an ample use of cross-references to suggest that, perhaps, there was more to knowledge than a simple hierarchy. Although here is visible a movement away from trees as the best structure of knowledge, that movement away should be separated from the concept of these structural diagrams as being transcendent, which was still very much in place. Chambers introduction to his tree read: "the Origin and Derivation of the several Parts, and the relation in which they stand to their common Stock and to each other; will assist in restoring 'em to their *proper Places* [emphasis added]." Knowledge, it seemed, still had a proper place, even if it might not be in a tree.



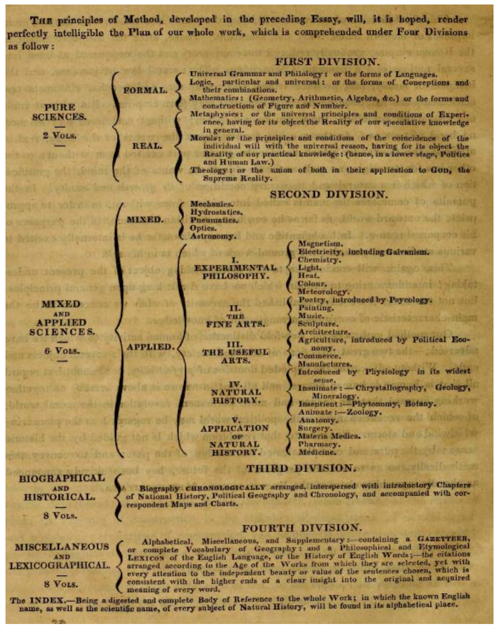
The great work of this movement was Diderot and d'Alembert's *Encyclopedie*. The encyclopedia is notable, among other reasons, because the editors claimed that unified orders of knowledge such as those of Descartes or his predecessors were essentially arbitrary; indeed, there were as many different systems as there were different projections of the world map (Ariew 1992). According to them, not only was there no such thing as a natural order to knowledge, there could not even be a proper genealogical order to knowledge. The editors are careful to separate those two concepts. In rejecting the definitive order of knowledge, however, the encyclopedists were still faced with a dilemma: their great encyclopedia still needed to be organized in some fashion. D'Alembert (1751, 1995) was eventually forced to use a single genealogical order, at least partially: "We have chosen a division which has appeared to us most nearly satisfactory for the encyclopedia arrangement of our knowledge and, at the same time, for its genealogical arrangement."

For all their wishes to rid themselves of a unified genealogy of science, the requirement to organize their encyclopedias and the logic of using traditional genealogical representations forced Diderot and d'Alembert into the same hierarchical trees as their predecessors. Chrétien Roth's 1769 diagram of all the sciences and the arts illustrated the encyclopedia using a naturalistic tree with hundreds of branches. Didirot and d'Alembert's own diagram of their encyclopedia's organization, while not an actual tree, still retained the same hierarchy they attempted to distance themselves from (Heller 2013). The preface of the third edition of the Encyclopedia Britannica (1797) contrasted itself against the earlier encyclopedias and their general classification systems. A later editor of Britannica noted that, although it was wise of d'Alembert to distinguish between the genealogy of the sciences and their arrangement on an intellectual map–a relatively new distinction–the use of such a map still undermined the inherent disunity of the sciences. The sciences were instead "perpetually blended in almost every branch of human knowledge," one of the Britannica editors noted (Yeo 1991). Here, for the first time, we begin to see people discussing science in terms of disunity; a trend which began with Frances Bacon's separation of knowledge into three distinct trees. A call for disunity was unsurprising, given how unwieldy and imbalanced these trees had clearly become. In fact, the very act of creating encyclopedias, separating individual articles into alphabetized chunks, was a catalyst for discussions of the disunity of science (Loveland 2006).





Although these comments were early indicators of a movement away from strict hierarchical views of knowledge, they were by no means the death knell. Samuel Taylor Coleridge's earl 19th century encyclopedia, *Metropolitana* (1818), was organized under an assumed genealogical and hierarchical scientific unity. Although Coleridge's encyclopedia had adopted the trend to move away from a single root of knowledge (in this case using Pure Sciences, Mixed & Applied Sciences, Biographical & Historical Knowledge and Miscellaneous & Lexicographical Knowledge as roots), it still retained the notion of a true and universal ontology of knowledge. Although this assumption is never stated outright, it is woven into the structure and goal of the encyclopedia. According to Coleridge, if every article is in the correct order, entries should only ever have to reference entries that occurred previously in the encyclopedia. There was a natural progression to knowledge, and his encyclopedia would follow it.


THE principles of Method, developed in the preceding Essay, will, it is hoped, render perfectly intelligible the Plan of our whole work, which is comprehended under Four Divisions as follow:

FIRST DIVISION.

PURE SCIENCES. — 2 VOLS. —

FORMAL.
- Universal Grammar and Philology: or the forms of Languages.
- Logic, particular and universal: or the forms of Conceptions and their combinations.
- Mathematics: (Geometry, Arithmetic, Algebra, &c.) or the forms and constructions of Figure and Number.

REAL.
- Metaphysics: or the universal principles and conditions of Experience, having for its object the Reality of our speculative knowledge in general.
- Morals: or the principles and conditions of the coincidence of the individual will with the universal reason, having for its object the Reality of our practical knowledge: (hence, in a lower stage, Politics and Human Law.)
- Theology: or the union of both in their application to GOD, the Supreme Reality.

SECOND DIVISION.

MIXED AND APPLIED SCIENCES. — 6 VOLS. —

MIXED.
- Mechanics.
- Hydrostatics.
- Pneumatics.
- Optics.
- Astronomy.

APPLIED.

I. EXPERIMENTAL PHILOSOPHY.
- Magnetism.
- Electricity, including Galvanism.
- Chemistry.
- Light.
- Heat.
- Colour.
- Meteorology.

II. THE FINE ARTS.
- Poetry, introduced by Psycology.
- Painting.
- Music.
- Sculpture.
- Architecture.

III. THE USEFUL ARTS.
- Agriculture, introduced by Political Economy.
- Commerce.
- Manufactures.

IV. NATURAL HISTORY.
- Introduced by Physiology in its widest sense.
- Inanimate: — Chrystallography, Geology, Mineralogy.
- Insentient: — Phytonomy, Botany.
- Animate: — Zoology.

V. APPLICATION OF NATURAL HISTORY.
- Anatomy.
- Surgery.
- Materia Medica.
- Pharmacy.
- Medicine.

THIRD DIVISION.

BIOGRAPHICAL AND HISTORICAL. — 8 VOLS.

Biography CHRONOLOGICALLY arranged, interspersed with introductory Chapters of National History, Political Geography and Chronology, and accompanied with correspondent Maps and Charts.

FOURTH DIVISION.

MISCELLANEOUS AND LEXICOGRAPHICAL. — 8 VOLS.

Alphabetical, Miscellaneous, and Supplementary: — containing a GAZETTEER, or complete Vocabulary of Geography: and a Philosophical and Etymological LEXICON of the English Language, or the History of English Words; — the citations arranged according to the Age of the Works from which they are selected, yet with every attention to the independent beauty or value of the sentences chosen, which is consistent with the higher ends of a clear insight into the original and acquired meaning of every word.

The INDEX. — Being a digested and complete Body of Reference to the whole Work; in which the known English name, as well as the scientific name, of every subject of Natural History, will be found in its alphabetical place.

Perhaps the ultimate 19th century culmination and conclusion of these true hierarchical classifications of knowledge came in the form of Charles Peirce's architectonic philosophy (Atkin 2005). Peirce's sprawling classification system, though without any one individual root, fell well within the Kantian tradition of a single unambiguous structure of knowledge which could eventually be reached, if one just tried hard enough. Peirce's work continued the earlier 19th century tradition of August Comte, who attempted to answer the question of how sciences reduced into one another.

In the mid-19th century, Herbert Spencer (1854, 1891) wrote that it was time to dispense once and for all the idea that a tree could be used to represent knowledge (Trompf 2011). He writes specifically against the notion of the sciences as the "branches of one trunk," suggesting that the notion that "the sciences had a common origin" is fundamentally flawed. Instead, the sciences "now and again re-unite […], they severally send off and receive connecting growths; and the intercommunion has ever becoming more frequent, more intricate, more widely ramified." Spencer goes on later to deeply criticize the notion of a "common root," writing that "however needful a succession may be for the convenience of books and catalogues, it must be recognized as merely a convention [with no] basis either in Nature or History." In short, knowledge is not a rooted thing, but an uprooted network: a non-hierarchical and non-genealogical interconnected web. For Spencer, the relationships between the sciences needed to be represented in a more multidimensional way (Van den Heuvel 2012). What replaced the unity of knowledge was not disconnected chaos, however, but an organization of knowledge into separate, distinct, and loosely connected disciplines (Yeo 1991), as evidenced by the various classification systems that cropped up by the late 19th and early 20th centuries.

NATURAL SCIENCE.

500 **Natural Science.**
501 Philosophy.
502 Compends.
503 Dictionaries.
504 Essays.
505 Periodicals.
506 Societies.
507 Education.
508 Travels.
509 History.
510 **Mathematics.**
511 Arithmetic.
512 Algebra.
513 Geometry.
514 Trigonometry.
515 Conic sections.
516 Analytical geometry.
517 Calculus.
518 Quaternions.
519 Probabilities.
520 **Astronomy.**
521 Theoretical.
522 Practical.
523 Descriptive.
524 Maps.
525 Observations.
526 Figure of the earth.
527 Navigation.
528 Almanacs.
529 Chronology.
530 **Physics.**
531 Mechanics.
532 Hydrostatics.
533 Pneumatics.
534 Acoustics.
535 Optics.
536 Heat.
537 Electricity.
538 Magnetism.
539 Molecular physics.
540 **Chemistry.**
541 Theoretical.
542 Experimental.
543 Analysis.
544 Qualitative.
545 Quantitative.
546 Inorganic.
547 Organic.
548 Crystallography.
549 Mineralogy.

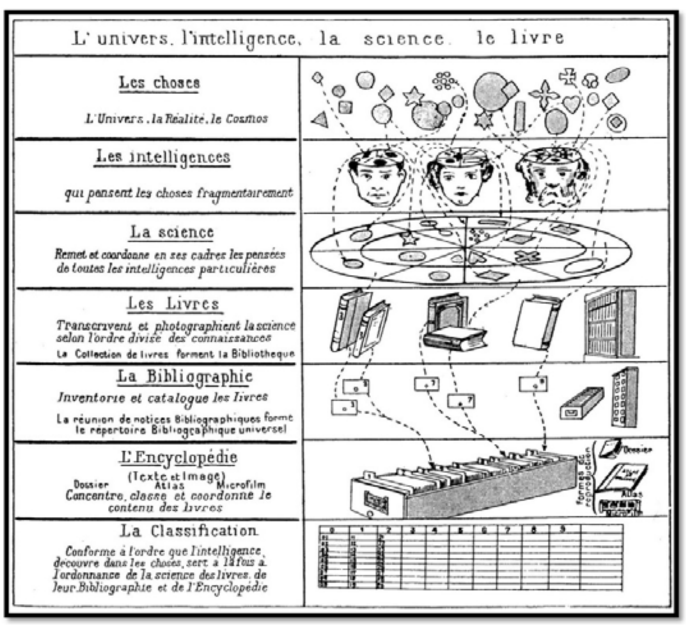
550 **Geology.**
551 Physical Geography, Meteorology.
552 Lithology.
553 Dynamical geology.
554 Europe.
555 Asia.
556 Africa.
557 North America.
558 South America.
559 Oceanica.
560 **Paleontology.**
561 Plants.
562 Invertebrates.
563 *Protozoa and Radiates.*
564 *Mollusca.*
565 *Articulates.*
566 Vertebrates.
567 *Fishes.*
568 *Reptiles and Birds.*
569 *Mammals.*
570 **Biology.**
571 Prehistoric Archaeology.
572 Ethnology.
573 Natural History of Man.
574 Homologies.
575 Evolution.
576 Embryology.
577 Spontaneous generation.
578 Microscopy.
579 Collectors' Manuals.
580 **Botany.**
581 Physiological.
582 Systematic.
583 Ornamental.
584 Europe.
585 Asia.
586 Africa.
587 North America.
588 South America.
589 Oceanica.
590 **Zoology.**
591 Comparative Anatomy.
592 Invertebrates.
593 *Protozoa and Radiates.*
594 *Mollusca.*
595 *Articulates.*
596 Vertebrates.
597 *Fishes.*
598 *Reptiles and Birds.*
599 *Mammals.*

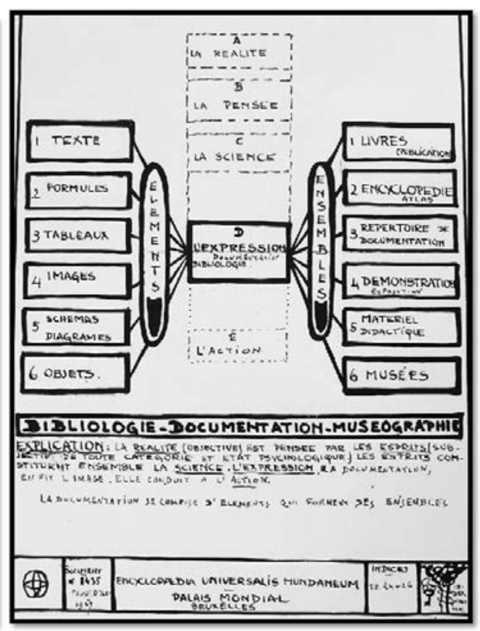
USEFUL ARTS.

600 **Useful Arts.**
601 Philosophy.
602 Compends.
603 Dictionaries.
604 Essays.
605 Periodicals.
606 Societies.
607 Education.
608 Patents.
609 History.
610 **Medicine.**
611 Anatomy.
612 Physiology.
613 Hygiene.
614 Public health.
615 Materia medica and therapeutics.
616 Pathology, theory and practice.
617 Surgery and dentistry.
618 Obstetrics and sexual science.
619 Veterinary medicine.
620 **Engineering.**
621 Mechanical.
622 Topographical.
623 Military.
624 Bridge.
625 Road and railroad.
626 Canal.
627 Harbor.
628 Hydraulic and mining.
629 Instruments and field books.
630 **Agriculture.**
631 Soil and preparation.
632 Pests and hindrances.
633 Productions of the soil.
634 Fruits.
635 Garden.
636 Domestic animals.
637 Dairy.
638 Bees and silkworm.
639 Fishing, trapping.
640 **Domestic Economy.**
641 Cookery.
642 Confectionery.
643 Food and dining.
644 Fuel and lights.
645 Furniture.
646 Clothing and toilet.
647 Servants.
648 Laundry.
649 Nursery and sick-room.

650 **Communication, Commerce.**
651 Writing.
652 *Penmanship.*
653 *Short hand.*
654 Telegraphy.
655 Printing.
656 Navigation and transportation.
657 Book keeping.
658 Business manuals.
659 Other.
660 **Chemical Technology.**
661 Chemicals.
662 Pyrotechnics.
663 Wines, liquors, and ales.
664 Sugar, salt, starch, etc.
665 Gas.
666 Glass.
667 Dyeing and bleaching.
668 Assaying.
669 Metallurgy.
670 **Manufactures.**
671 Metals.
672 *Iron.*
673 Marble, stone, and brick.
674 Wood.
675 Leather and rubber.
676 Paper.
677 Textile fabrics.
678 Cotton.
679 Other.
680 **Mechanic Trades.**
681 Watch and instrument making.
682 Blacksmithing.
683 Lock and gun-making.
684 Carriage and cabinet-making.
685 Saddlery and shoe making.
686 Book binding.
687 Clothes-making.
688
689 Other.
690 **Building.**
691 Materials.
692 Plans and specifications.
693 Masonry.
694 Carpentry.
695 Slating and tiling.
696 Plumbing.
697 Warming and ventilation.
698 Painting, glazing, and paper-hanging.
699 Car and Ship-building.

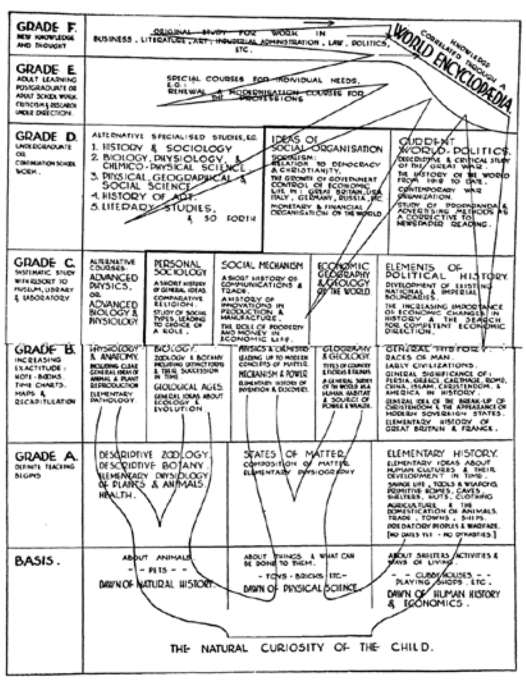
Paul Otlet, heavily influenced by Spencer and the Dewey Decimal System (Acker 2012), co-created the Universal Decimal Classification (UDC) scheme in the early 20th century. Using a system of combinable facets, the scheme took the multidimensionality of knowledge relationships into account far better than the earlier strict tree hierarchies. Otlet sought to represent this multidimensionality visually, intentionally breaking with the arboreal visual metaphors in the past in lieu of more mechanical, rather than natural, diagrams. While he employed a large variety of visual techniques, many of Otlet's illustrations featured non-hierarchical network-like representations of classification, with circuitous paths and no discernible trunk or preferred hierarchy (Smiraglia and Van den Heuvel 2011; Van den Heuvel 2012). According to Rayward (1994), this classification scheme would ideally lead to "an immense map of the domains of knowledge."





The early-to-mid twentieth century history of classification includes many examples of increasingly nuanced understandings of the multidimensional relationships between and within the sciences. S.R. Ranganathan, drawing inspiration from Otlet, created the fully faceted colon classification scheme in 1933, which is hierarchical but allows knowledge to be classified flexibly and in many dimensions. J.H. Shera, in 1951, writes on the incompatibility of traditional hierarchical schematizations of knowledge with the actual multidimensional nature of the intellectual space (Van den Heuvel 2012). Instead of replacing tree visualizations with something more flexible, these classification theorists were in most cases content to dispense of illustrations altogether. At this point, network visualizations had not yet taken hold but in some small corners of sociology (Kruja et al. 2002). In fact, well into the middle of the 20th century, classification theorists were still invoking the natural metaphor of a tree, stretching it ever-further. An exchange between Ranganathan and Donker Duyvis (Ranganathan 1950, 100; Donker Duyvis 1951, 99–100) likened knowledge to a Banyan, a fig tree from India that grows multiple trunks and expands in every direction like a vast network of wood. Ranganathan wrote “A decimal number is like a coconut palm tree. It can only grow at the top. But the Colon Number is like the banyan tree which can grow in all directions simultaneously.” Donker Duyvis, in reply, wrote that the UDC system is also like a banyan tree, and that the resulting flexibility ensures “that no philosophical or scientific system can any longer be recognized as the base of the UDC.” The botanical metaphor is stretched even further by the late 20th century with philosophers Deleuze and Guattari (1987), who attempted to dispense of hierarchies and trees altogether by invoking the concept of a rhizome, a root-mass which can (and must) shoot in every direction, creating odd connections and lacking any center.

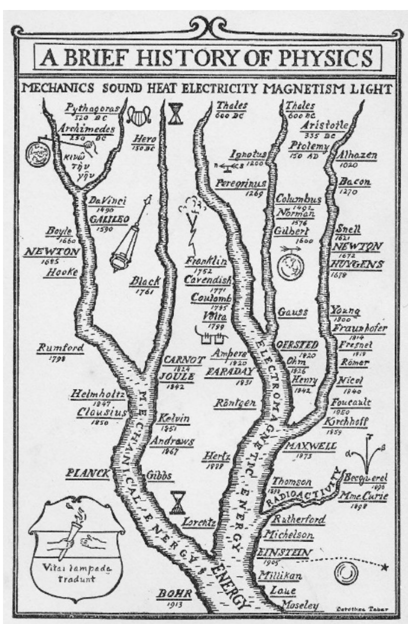
Inspired by Otlet, H.G. Wells’ *World Brain* (1937; 1938) set forth his vision of a new World Encyclopedia, connecting and organizing the world’s knowledge together. He illustrated part of his idea with a map, not of how knowledge is intrinsically organized, but of how children ought to be taught about the world. The diagram bridges the old tree illustrations with what would become the new standard of diffuse interconnections. The bottom presents a tree whose root is not God or philosophy, but the natural curiosity of a child, and the top a star-burst of the world encyclopedia casts light into each scholarly domain, subtitled “knowledge correlated through a world encyclopedia.”

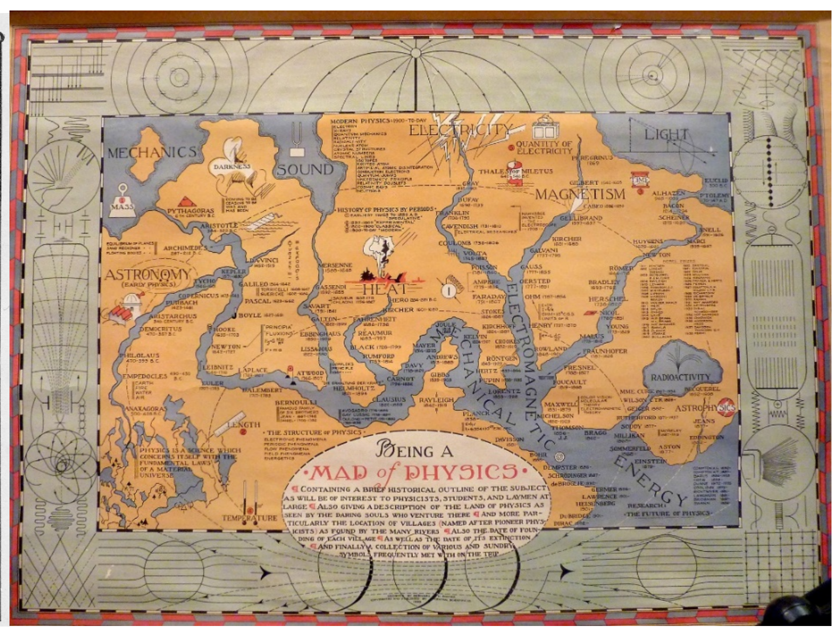


The middle third of the 20th century saw very few visualizations from classification theorists. Most illustrations, like many histories of science from that time period, came from elsewhere, especially in the sciences. Sometime between 1915 and 1925, artist Dorothea Taber created “A Brief History of Physics,” an illustration which eventually found its way into popular physics textbooks (Duff 1926). Taber’s illustration, which matched the impression within physics at the time, turned the old hierarchical genealogical diagrams on-end. Instead of one trunk of physics branching to form its many subdisciplines, Taber's illustration represented physics as a series of tributaries feeding into the larger river of knowledge. Mechanics, sound, heat, electricity, magnetism, and light all eventually combined to become modern physics. Taber reversed the flow of the genealogy, flipping the hierarchy on its head.

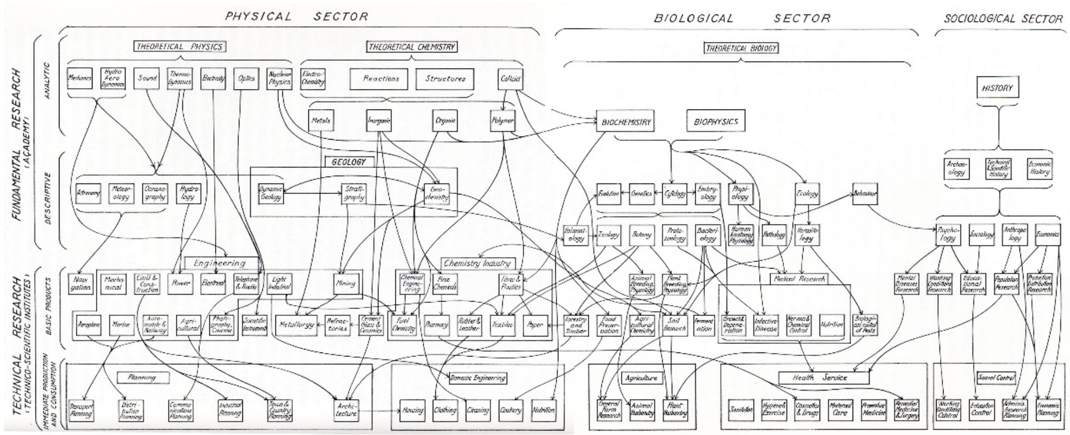
This shift bears a similar philosophical weight as when Bacon in 1605 wrote "the age of antiquity is the youth of the world," showing that it was not the Ancient Greeks who bore the wisdom of the old and wise; instead, the modern day should be called ancient, for it receives the benefits and wisdom of old age. In this statement, Bacon situates knowledge as progressive, accumulating over time, juxtaposed against the "medieval" idea that we can only hope to approach what the ancient civilizations already learned. It took another three hundred years for our representations of knowledge to catch up to that shift, at once breaking from a divine or perfect origin of science, and foreshadowing the rhetoric of reunification and consilience. The earliest discussions of the unity of science placed it at its genealogical origins; eventually, when the idea became untenable, it was thrown out entirely. Here we see its reintroduction at the end of the genealogy, the point where science is working towards. This too will soon be replaced with networked concepts of unity and consilience, which dispense both with hierarchy and genealogy.

The hierarchical notions of knowledge were the first to go in the early 20th century wave of illustrations. In 1939, physicist Bernard H. Porter copied and extended Taber's map, projected physics history onto a geographically-inspired layout with many of the same tributaries and names as Taber's. The map was published in a number of early physics textbooks, and used as an aid to education. While it could be traced hierarchically, the visual layout eschewed such interpretation.





That same year, physicist-turned-historian John D. Bernal illustrated *The Social Function of Science* (1939, 1944) with a diagram which, at first glance, might be confused with the hierarchical tree diagrams prefacing earlier encyclopedias. In the end, over a hundred knowledge domains appear in the hierarchy. What sets this tree apart is the arrows that cross the hierarchies, creating sideways relationships and representing the non-linear and often social interactions between the disciplines (Börner 2010).

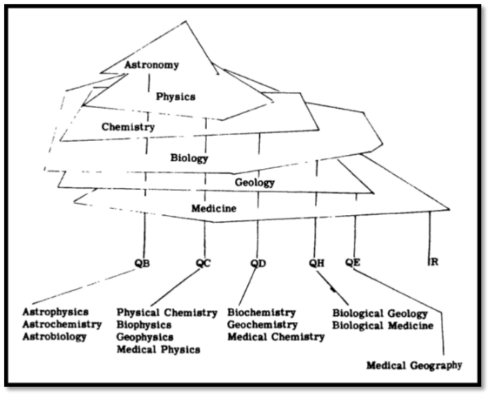


Börner, Katy. *Atlas of Science: Visualizing What We Know.* (2010). The MIT Press. Pg 11.

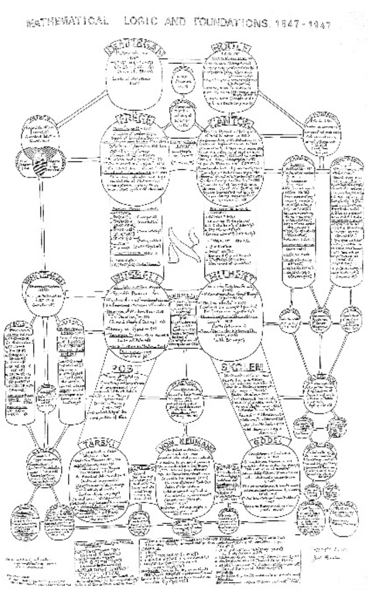
A decade later, in 1948, chemist H.J.T. Ellingham produced a hand-drawn map showing the relationships between the branches of science and technology (Börner 2010). While visually similar to H.G. Wells' map, in its use of square sections for each domain of knowledge fittingly snuggle against one another, the fundamental difference is the lack of any frame of reference. The bottom is not the mind of a child and the top not that of an adult; instead, they are simply laid out in whatever way would allow each domain to fit on the page. Adjacent domains of knowledge are related, and non-adjacent ones are not. Ellingham used this map as a way to direct practitioners of science toward scientific literature by drawing clouds overlapping and between disciplinary squares, as a sort of library classification scheme.

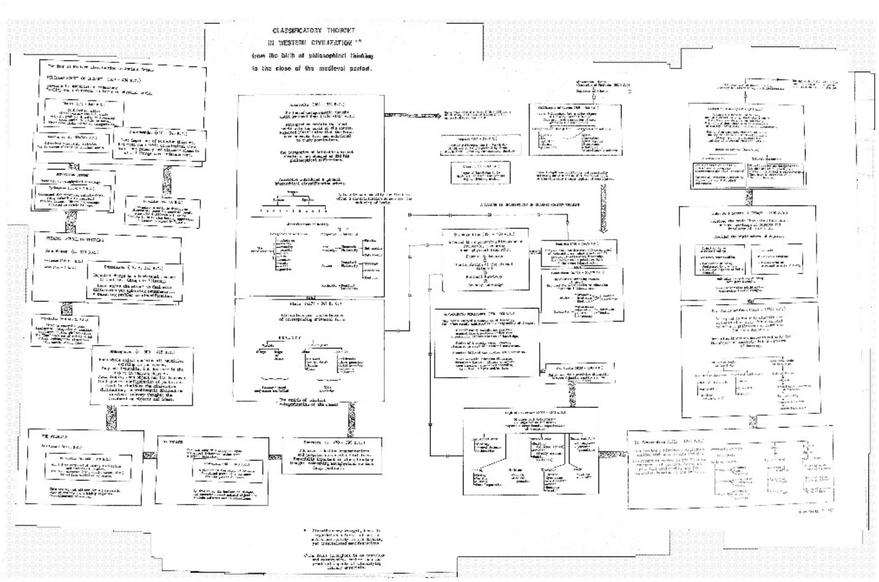
Börner, Katy. *Atlas of Science: Visualizing What We Know.* (2010). The MIT Press. Pg 27.

A select few classification theorists, like Phyllis Richmond, attempted to speculate how multidimensional classifications might be visualized (Richmond 1954), but the technology was not yet available to bring the illustrations beyond mere speculation. It was not until the 1950s that modern-style network visualizations reached standard use across many domains, and not until the 1970s that computers made relatively complex networks easy to visualize (Freeman 2000).



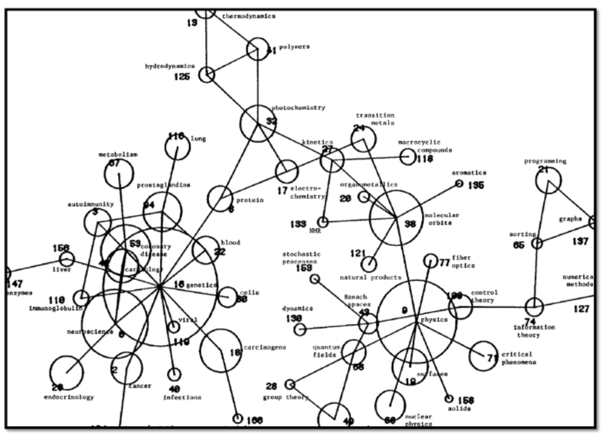
While automatic computationally generated diagrams of knowledge were becoming possible as early as the 1970s, it was not uncommon for researchers to make hand-created diagrams of their own disciplines, as with Porter's 1939 map of physics shown earlier. At Indiana University, one such scholar created a diagram of the history of mathematics and logic that was reminiscent of *ilanot*, or Kabbalistic network-style diagrams which stem from the same tree traditions as these knowledge diagrams (Friedman 1976). Classification theory itself was not immune from such attempts; Ivan Gaetz (1988) created a genealogical diagram of the history of classification theory. While it was ordered, the diagram had no particular hierarchy, and featured the sort of cross-connections common among network representations. A more recent creation by Kevin Scharp (2010) charts the history of western philosophy from 600 B.C.E. to 1935 C.E., and is clearly genealogical while also being a non-hierarchical, interconnected web. Scharp's diagram is nearly 50 feet tall when printed out, and is not reproduced here. These sort of genealogical, non-hierarchical disciplinary histories are becoming fairly common, and are notable when compared against earlier diagrams for their lack of any individual root, and for the extent to which they shy away from any claims to transcendence or universality.



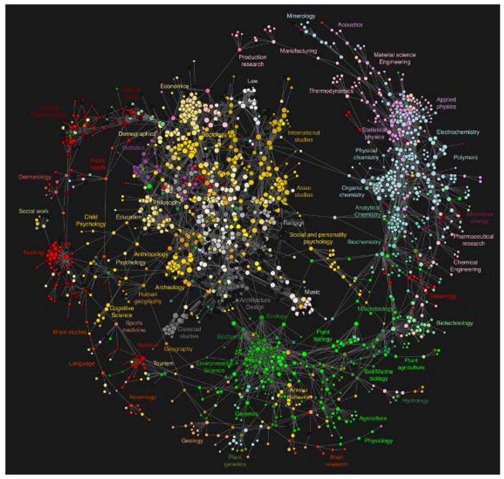


Over this same period, researchers outside of traditional classification theory had begun drawing citation networks between scientific articles and books. Even the most genealogical among these diagrams shied away from formal trees, highlighting instead the interconnections between scientific literature. Paper citations eventually abstracted to author- or journal-level metrics, which themselves abstracted to information networks between disciplines or domains. These maps were sometimes represented as formal network graphs, other times as spatial distance graphs, but by this point the tree metaphor was rarely invoked. By this time, as well, the so-call unity of knowledge was rarely brought up.

The unification rhetoric returned in force with bibliometrics, and it was not long until bibliometricians began attempting to unify entire citation databases into renewed, computationally generated maps of science. By 1973, large-scale citation and clustering analyses were being used to map the macrostructures of knowledge to specific domains (Marshakova-Shaikevich 1973), and by 1985 the entire ISI citation database was being used for this purpose (Small and Garfield 1985). Within a decade, sophisticated techniques were being used to map both internal and external structures of science, combining nested subdisciplines and connections between them (Small 1999). At this point, the rhetoric had moved to a unity of science, rather than a unity of knowledge. The diagrams that before had attempted to relate all the concepts that ruled life in the universe were now relegated to mapping C.P. Snow's culture of science (Snow 2007).

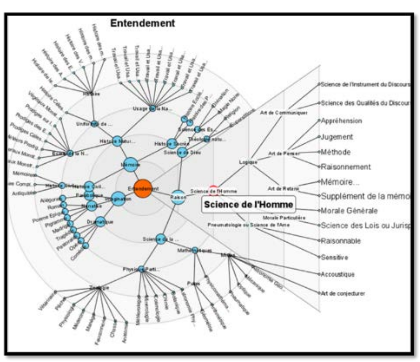


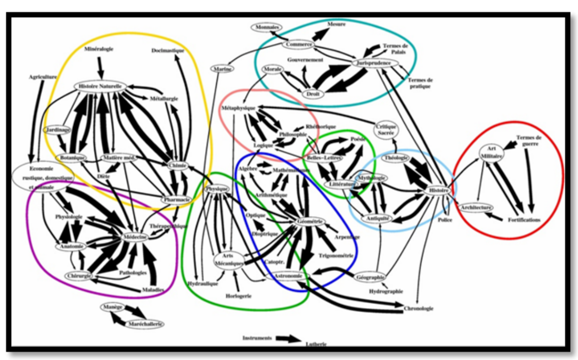
As citation analysis and science mapping took root, the well-known story beginning with Vannevar Bush's "As We May Think" (1945) and spanning the next half-century was also unfolding, eventually resulting in hypertext and the World Wide Web. One solution to navigating the world's information, suggested by Ted Nelson (1974), was the Xanadu project. It was "a new form of interconnection for computer files – corresponding to the *true interconnection of ideas* [emphasis added] – which can be refined and elaborated into a shared network." After the development of the World Wide Web, Nelson fought against the use of hierarchies in organizing knowledge, preferring a multidimensional method of navigation, and creating some network-like visualizations to support this concept (Van den Heuvel 2012). Many network-based visualizations have since been published mapping both the web in general, and knowledge domains in particular (Bollen et al. 2009).



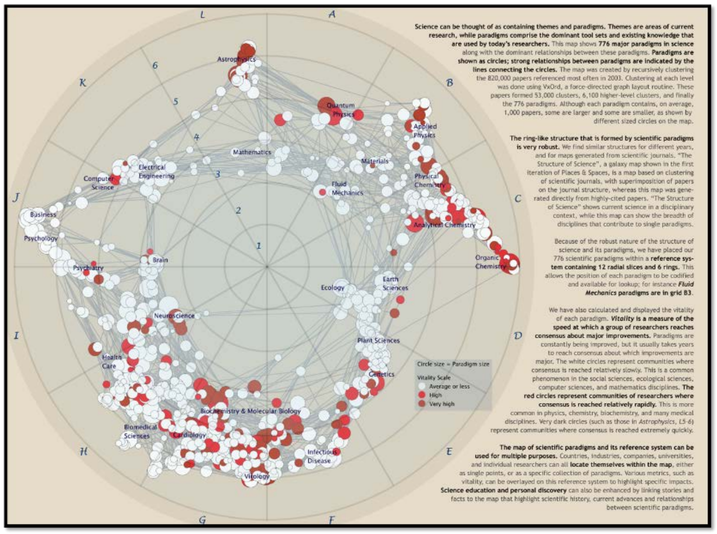
The history of information retrieval on the web mirrors to some extent this history of classification schemes. In 1994, two Stanford graduate students founded Yahoo!, a directory of the World Wide Web. It presented a carefully curated and deeply nested hierarchy of indexed web pages; an attempt to organize the world's information. Four years later, two other Stanford graduate students founded Google, a search engine which intentionally replaced hierarchies with targeted and intelligently-sorted search results. Within a few years, Yahoo! got rid of its nested web directory, and began relying on Google to power its portal to the web.

In the last decade, a number of researchers have revisited the *Encyclopédie* of Diderot and d'Alembert, putting together structures and visualizations that would undoubtedly have made the editors proud. In 2006, Christophe Tricot mapped the Diderot and d'Alembert's tree onto an interactive globe which could be explored dynamically (Lima 2006). Concurrently, however, researchers were attempting to map the *Encyclopédie* using the article's cross-references, rather than the initial tree of classification, in order to explore the underlying structure of knowledge domains through the articles themselves (Blanchard and Olsen 2002). The same group later created a map of knowledge domains in the *Encyclopédie* via the co-occurrence of words within each article (Cooney et al. 2008). These efforts resulted in network graphs not dissimilar from the maps of science of becoming popular in bibliometrics.

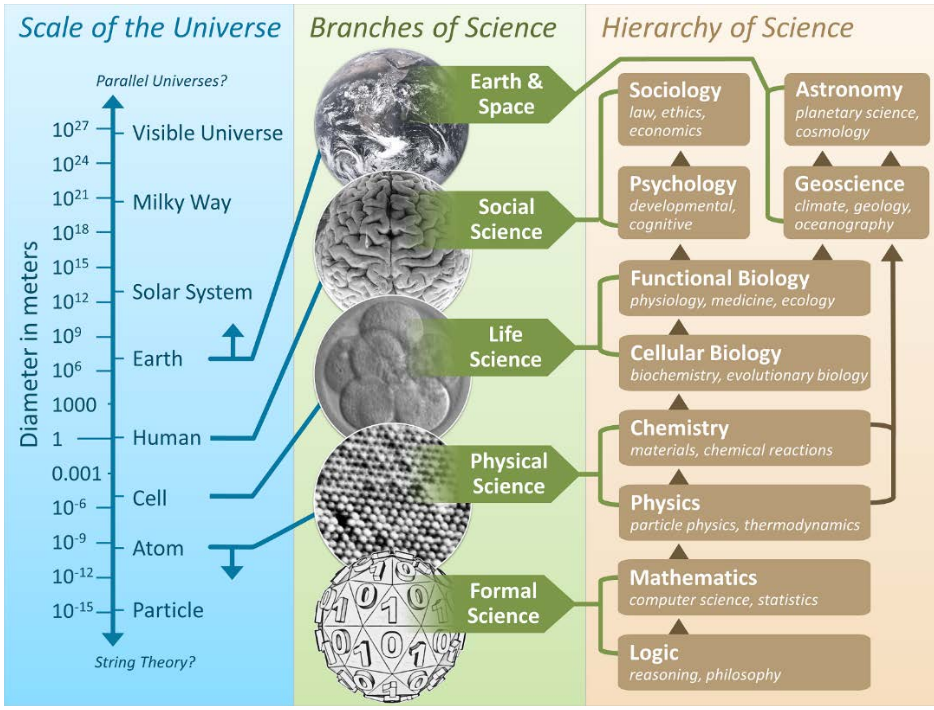


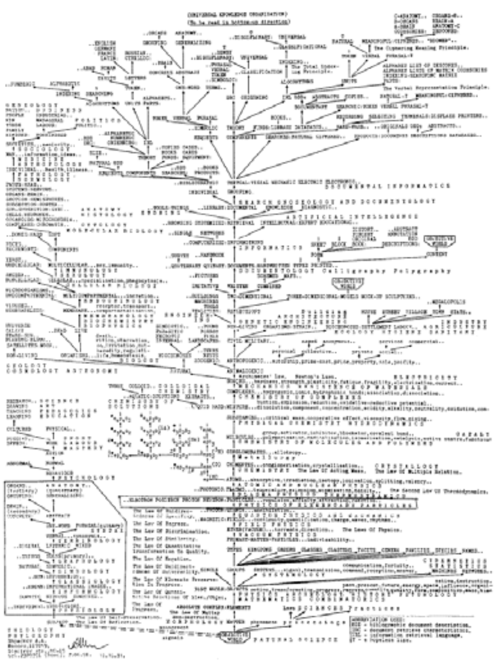


By 2009, enough science maps existed to warrant a consolidation and standardization effort (Klavans and Boyack 2009). Klavans and Boyack, in making a consensus map of science, are quick to point out that these maps to not attempt to correspond to any ontology of knowledge. This is a far stretch from medieval knowledge maps, which illustrated the relationships between concepts as they actually were, or even 18th and 19th century illustrations of the universe of encyclopedic knowledge, which would represent genealogies as at least one possible ontology of knowledge. Contemporary maps of science have displaced both the formal hierarchies of what came before, as well as the notion that these illustrations represent any more than a useful way to understand and navigate the social and structural landscape of science as it is practiced. The concept of a root or central trunk had been dispensed of entirely, replaced by a more relativist sense that each domain has its own central perspective. As C.S. Lewis (1943) aptly wrote in an unrelated novel, “there seems no centre because it’s all centre.”



While this postmodern theory of classification has taken root in the majority of minds both within and outside contemporary classification research, it should by no means suggest those feelings are unanimous. A Russian researcher, A.A. Shpackov (1992), recently submitted his own “Universal Knowledge Organization” to *JASIST*, a leading information science journal, which was itself a very clear tree organizing all the world’s knowledge. Notably, the top of the *Wikipedia* page for “Science” (2014) includes a basic sketch of the “Hierarchy of Science” which conforms to notions of consilience. Other current organizational schemes do still utilize nested hierarchies, but do not take these schemes as universal. The Indiana Philosophy Ontology Project (Allen et al. 2014) uses machine learning to infer a nested hierarchy of the relationship between concepts in philosophy; however, this hierarchy is presented as one of functional convenience, and the service provides ample cross-linkages between branches.





PRESCRIPTION, STRUCTURE, AND VISUALIZATION

Our view of the order of the world and our knowledge about it has changed dramatically in the last thousand years. Ontology and genealogy were once tightly interwoven with knowledge, concepts, and objects in a structured hierarchy, but each of those have since been separated out and become more structurally diffuse. Throughout this history, knowledge has alternatingly been seen as a unified whole or a disconnected chaos. It has never been completely clear to what extent visual and arboreal metaphors have influenced our understanding of knowledge, and to what extent our understanding of knowledge has influenced our use of metaphors.

With this in mind, there is a deeply normative and moral angle to a self-conscious shift in visualization strategies. A modern world ever-filling with visualizations and rhetorical structures which emphasize diffuse networks and webs in turn reinforce our tendency to see these webs in places they are perhaps not as relevant. If the conscious decision is made to begin aligning knowledge classification structures with the web-like visualizations now common in other domains, a scholarly society already primed to networked thinking and the decentering of hierarchies will only further lose any sense of primacy or order in its ontology of knowledge. The carefully structured cosmos of ancient knowledge would be further supplanted by the chaos of disciplines. At its most absurd logical conclusion, no domain of knowledge or pseudoscience would have any genealogical or epistemological claim to superiority or centrality when the ontology of knowledge itself can make no claims to either. While this conceptualization may fit well within some understandings of a post-modern world, others might find fault with the premise. A word of caution, then, is warranted to any who read this history as a victorious narrative, resulting in the inevitable true and proper understanding of knowledge as a diffuse web.

The structure of knowledge and its relationship to the world it describes has a profound influence to academia particularly. What funding and positions are available are often allocated according to disciplinary affiliation, and prestige is often granted to some domains at the expense of others. The availability of funding at all, governmental or industrial, is contingent on the relationship of knowledge to the world around it. A knowledge disconnected from the world and disconnected within itself will lose its relevance, as is very noticeably happening in the modern American university system.

We have begun to see a movement away from force-directed networks as a means of visualization, with the awareness that they are often too chaotic to convey information reliably. A number of alternatives are cropping up in their place, some retaining the network metaphor, and some adopting other metaphors, like geographic landscapes. It is not yet known how this will influence our understanding of knowledge.

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