

02 | From Trees to Networks

In simplicity of structure the tree is comparable to the compulsive desire for neatness and order that insists the candlesticks on a mantelpiece be perfectly straight and perfectly symmetrical about the centre. The semilattice, by comparison, is the structure of a complex fabric; it is the structure of living things, of great paintings and symphonies.

—Christopher Alexander

We're tired of trees. We should stop believing in trees, roots, and radicles. They've made us suffer too much. All of arborescent culture is founded on them, from biology to linguistics. Nothing is beautiful or loving or political aside from underground stems and aerial root, adventitious growths and rhizomes.

—Gilles Deleuze and Félix Guattari

Besides its evocative symbolism and undeniable applicability in different types of organizational contexts, the hierarchical tree model has innumerable connotations that have been occasionally criticized. Many opposing voices, usually highlighting its most pernicious attributes, have refuted the centralized, top-down

tree metaphor, advocating for flexible alternative models able to accommodate the complex connectedness of modern society. The first disapproving view associates trees with the notion of centralism, or centralization, which expresses either an unequivocal concentration of power and authority in a central person or group of people, or a particular

The two epigraphs to this chapter are drawn from Alexander, "A City is Not a Tree," 58–62; and Deleuze and Guattari, *A Thousand Plateaus*, 15.

system in which most communications are routed through one central hub. Centralism is also linked to other less reputable concepts, such as totalitarianism, authoritarianism, and absolutism—typical of severely oppressive hierarchical systems.

In *The Tree of Life* (2007), Guillaume Lécointre and Hervé Le Guyader provide two additional views associated with the widespread concept of trees: finalism and essentialism.¹ Finalism, as the name implies, envisages a world where everything flows toward a predetermined final goal. Essentialism has an absolute understanding of the nature of being, in which every entity has a set of properties belonging to a precisely defined kind or group. It sees the essence of things as permanent, immutable characteristics—a fundamental rule for the enduring tree organization. If finalism describes the unidirectional courses of trees, essentialism alludes to their inert branches, which never shift or interact. Given that centralism, finalism, and essentialism form the basis of a common tree arrangement, we might also describe it as an authoritarian, unidirectional, and stagnant model.

In part due to its aforementioned traits, the tree model has been attacked, most notably by French philosophers Gilles Deleuze and Félix Guattari, who, in response, developed an antagonistic philosophical theory. Deleuze and Guattari oppose trees due to their forced totalitarianism and despotism—they are always dependent on a central authority. The authors argue in *A Thousand Plateaus* (1987) that trees are a condition of theoretical rigidity and unidirectional progress, where everything returns to a central trunk through vertical and linear connections. Trees therefore embody an organization that has never truly embraced multiplicity.

In opposition to this authoritarian model, Deleuze and Guattari in their *Capitalism and Schizophrenia* (1972–80) propose the concept of *rhizome*, aimed at acknowledging multiplicities and multilinearity: “In contrast to centered systems with hierarchical modes of communication and pre-established paths, the rhizome is an acentered, nonhierarchical, nonsignifying system without a General and without an organizing memory or central automaton, defined solely by a circulation of states.”² Distinct from a tree topology and its individual branches, the rhizome connects any point to any other point, in a transverse and autonomous way, allowing for a flexible network of intercommunicability to emerge. “The rhizome pertains to a map that must be produced, constructed, a map that is always detachable, connectable, reversible, modifiable, and has multiple entryways and exits and its own lines of flight.”³

The rhizomatic model is a significant influence in postmodern thinking, particularly in areas like communication theory, cyberspace theory, complex systems, nonlinear narrative, and hypermedia. But perhaps one of the most famous demonstrations of the principle’s applicability is hypertext. Pertaining to any text with references (hyperlinks) to other texts, hypertext is the fundamental building block of the World Wide Web—arguably the largest rhizomatic system ever created by man. But rhizomatic theory also helps us apprehend the intricacies of the world: the rhizome is not a self-imposed conjectural view on our existence, but a fundamental topology of nature and an underlying element to the complex fabric of life. Perhaps for this reason, the rhizome has become a philosophical mentor in the ongoing struggle of modern science to cope with increasingly complex challenges.

fig. 1

Warren Weaver’s concept of the three stages of modern science, according to the type of problems it tried to solve—problems of simplicity, problems of disorganized complexity, and problems of organized complexity—as discussed in Weaver, “Science and Complexity” (1948)

A few decades before Deleuze and Guattari's conception of the rhizome, American scientist Warren Weaver was already aware of the inherent complexities of nature and the hurdles anticipated by the scientific community in deciphering them. In 1948 in an article entitled "Science and Complexity," Weaver divided the history of modern science into three distinct stages: The first period, covering most of the seventeenth, eighteenth, and nineteenth centuries, encapsulated what he denominated as "problems of simplicity." Most scientists during this period were fundamentally trying to understand the influence of one variable over another. The second phase, taking place during the first half of the twentieth century, involved "problems of disorganized complexity." This was a period of time when researchers started conceiving systems with a substantial number of variables, but the way many of these variables interacted was thought to be random and sometimes chaotic. The last stage defined by Weaver, initiated in the second half of the twentieth century and continuing to this day, is critically shaped by "problems of organized complexity." Not only have we recognized the presence of exceedingly complex systems, with a large number of variables, but we have also recognized the notion that these variables are highly interconnected and interdependent. fig. 1

In reference to the last stage, Weaver wrote in 1948:

These problems [such as commodity price fluctuation, currency stabilization, war strategies, or the behavioral patterns of social groups]—and a wide range of similar problems in the biological, medical, psychological, economic, and political sciences—are just too complicated to yield to the old nineteenth century

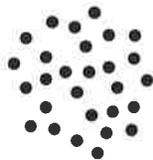
techniques which were so dramatically successful on two-, three-, or four-variable problems of simplicity.... These new problems, and the future of the world depends on many of them, requires science to make a third great advance, an advance that must be even greater than the nineteenth century conquest of problems of simplicity or the twentieth century victory over problems of disorganized complexity. Science must, over the next 50 years, learn to deal with these problems of organized complexity.⁴

Weaver's paper has been a great influence on contemporary thinking about complexity and the emergence of recent fields like complexity science and network theory. The conjecture he made for the second half of the twentieth century, and the advancement of science in dealing with increasingly complex challenges, is as true now as it has ever been. As we will see throughout this chapter, many of our contemporary hurdles, from the way we organize our cities to the way we decode our brain, concern problems of organized complexity that cannot be portrayed, analyzed, or understood by employing a centralized tree metaphor. In opposition to top-down hierarchies, these new challenges deal primarily with rhizomatic properties such as decentralization, emergence, mutability, nonlinearity, and ultimately, diversity.

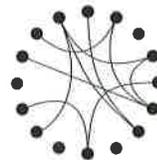
The complex connectedness of modern times requires new tools of analysis and exploration, but above all, it demands a new way of thinking. It demands a pluralistic understanding of the world that is able to envision the wider structural plan and at the same time examine the



17th, 18th, and 19th Centuries
Problems of Simplicity



First half of the 20th Century
Problems of Disorganized
Complexity



Post -1950
Problems of Organized
Complexity

intricate mesh of connections among its smallest elements. It ultimately calls for a holistic systems approach; it calls for network thinking.

Planning a City

In 1965 the influential architect Christopher Alexander, most famously known for his book *A Pattern Language: Towns, Buildings, Construction* (1977), wrote one of the most influential pieces of postmodern criticisms on architecture, a short essay entitled "A City is Not a Tree." In it, Alexander refutes the hierarchical and centralized organization of the urban landscape, characteristic of model cities such as Brasilia, in favor of organic cities like London and New York. He declares that many of these artificial cities have failed due to the rigid and insipid thinking of their creators, who planned areas of activity (e.g., residential, industrial, commercial) as independent and incommunicable modules, in a typical tree structure of separate branches.

Although we have become accustomed to this type of stringent urban layout, it is a fairly recent conception. Before the Industrial Revolution, most people lived in residential spaces located above their work environment, and the line between personal and professional spheres was very thin. The effects of industrialization meant that people lived in one area of town, worked in another, and probably shopped in yet another area. Anyone who has ever lived in a large city with its sprawling suburban areas knows how this segregation translates to lengthy daily commuting time. ^{fig. 2} Alexander is extremely forthright about the consequences of this fragmentation: "In any organized object, extreme compartmentalization and the dissociation of internal elements are the first signs of coming destruction. In a

society, dissociation is anarchy. In a person, dissociation is the mark of schizophrenia and impending suicide."⁵ As Alexander clearly implies, human beings do not naturally comply with this highly compartmentalized *modus operandi*. Our connections, among ourselves and with the surrounding environment, do not follow this type of conceptual order and simplicity. We are ambiguous, complex, and idiosyncratic. "The reality of today's social structure is thick with overlap—the systems of friends and acquaintances form a semilattice, not a tree,"⁶ states Alexander on the convergent nature of social groups. He is convinced that the reductionist conception of urban spaces, typical of a tree organization, blinds our judgment of the city and limits the problem-solving abilities of many planners and system analysts.

Alexander understands well the invisible mesh of interconnections that overlays the urban environment and suggests a semilattice organization, similar to a network, that can better suit the complexities of human relationships. Due to its structural intricacy, the semilattice is a source of rich variety. Within the semilattice the "idea of overlap, ambiguity, multiplicity of aspect [are not] less orderly than the rigid tree, but more so.... They represent a thicker, tougher, more subtle and more complex view of structure."⁷ Alexander finishes the article with the unequivocal assertion that "the city is not, cannot and must not be a tree.... The city is a receptacle for life."⁸ ^{fig. 3}

Published four years before Alexander's piece, Jane Jacobs, in the classic *The Death and Life of Great American Cities* (1961), delivers a biting criticism of the urban calamities perpetrated in the United States during the 1950s, which caused social alienation by isolating a large number of communities and urban spaces. The book also offers

fig. 2

Brandon Martin-Anderson, *Shortest Path Tree*, 2006

Street and transit information are inputted into software that computes the shortest routes between one specific location and the remaining areas of town (San Francisco). The width of a branch (route) is proportional to the sum of branches reachable by that branch,

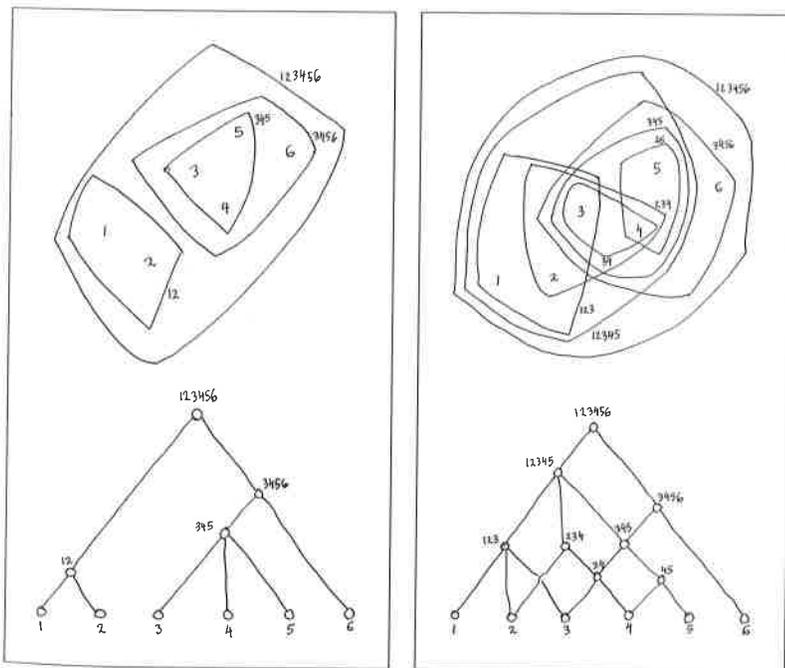
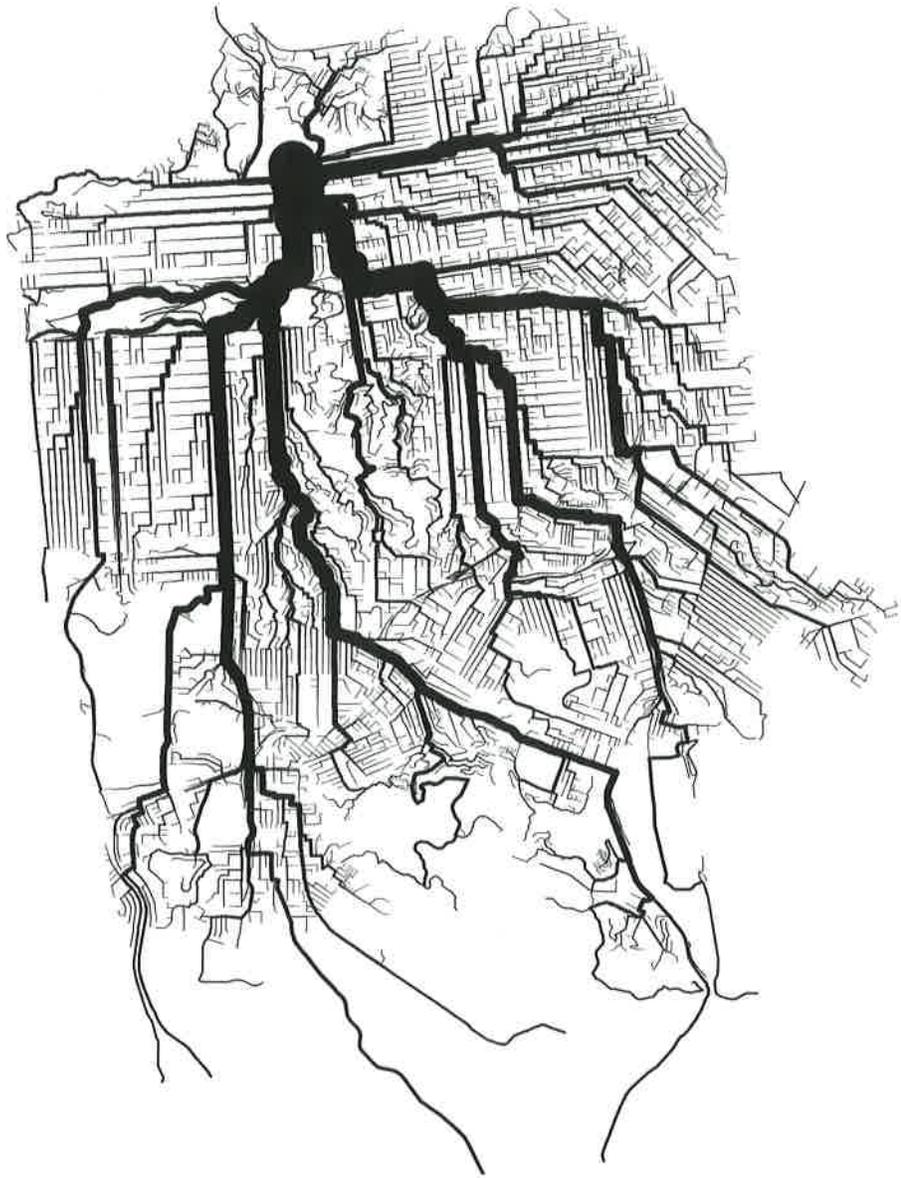


fig. 3

Nikos Salingaros, *Tree versus semilattice*, 1965

A set of diagrams that appeared in Christopher Alexander's essay "A City is Not a Tree" (1977), which complemented his discourse on the different ways to organize a city. It shows the scheme of a simplified tree model (left), which excludes the likelihood of overlapping areas, and a more tolerant semilattice (right), which allows for different urban layers to coexist.

a convincing exaltation for organicism—a philosophical notion that proposes that reality is best understood as an organic whole. Jacobs eloquently describes the aim of her book in the very first introductory paragraph: “This book is an attack on current city planning and rebuilding. It is also, and mostly, an attempt to introduce new principles of city planning and rebuilding, different and even opposite from those now taught in everything from schools of architecture and planning to the Sunday supplements and women’s magazines.”⁹ She opposes any simplified or ingenuous plan of a city, and in reference to Weaver’s original thesis, Jacobs states, “Cities happen to be problems in organized complexity, like the life sciences. They present situations in which a half-dozen or even several dozen quantities are all varying simultaneously and in subtly interconnected ways.”¹⁰ Jacobs reiterates that contemporary urban planning has obliterated the city, because it has rejected its main actors—human beings.

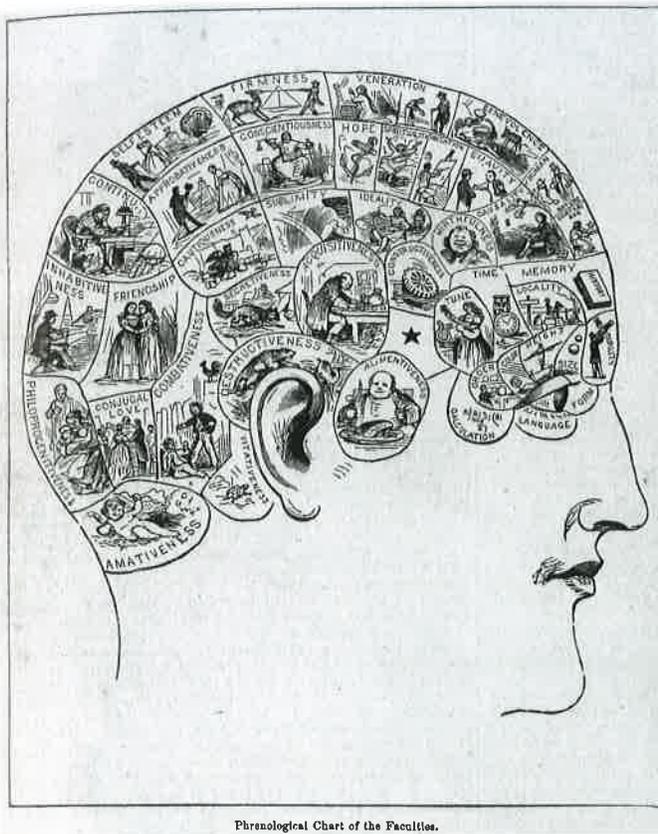
The work of Jacobs and Alexander has been fundamental in the emergence of New Urbanism, a movement started in the 1980s with the goal of investigating a more efficient integration between the primary uses of a city. Even though this movement has caused various new developments to emerge in the last decades across the globe—promoting pedestrian-friendly neighborhoods, green-building construction, historic preservation, and a balanced development between jobs and housing—we still have a long way to go. This much needed transformation will have to acknowledge the city as a living organism in constant mutation, a highly complex network involving a vast number of variables. It will have to conceive the city as an open space bursting with overlap and spontaneity, where the natural conditions for creativity, recreation, and

cooperation can easily prosper. This will only happen if we stop imposing artificial barriers on our spaces and truly embrace the diverse social nature of man.

Neural Landscape

The study of the brain has truly come a long way. Ancient accounts, dating back to Greek philosophy, indicate an early belief in the assessment of one’s character or personality (e.g., criminality) from one’s facial features (e.g., distance between the eyes), in what became commonly referred to as “physiognomy.” It is not surprising that, as social beings, people would associate outer appearance with inner character. This became a widespread conviction that was held by many prominent figures of antiquity, including Aristotle.

Toward the eighteenth century, researchers abandoned the study of facial features to pursue the study of the skull itself. And by 1796, by the hands of German physician Franz Joseph Gall, the pseudoscience of phrenology was born. Phrenologists believed that the shape of the skull, with its bumps and hollows, exposed the thoughts within. Believing that the mind was made up of different mental faculties represented in distinct areas of the brain, phrenologists measured the cranial bone to find the engorged or shrunken areas of the skull that corresponded to the area of the brain responsible for a particular personality trait, character, or behavior. Gall’s list of the “brain organs” contained twenty-seven different regions, including “the love of one’s offspring,” “the carnivorous instinct; the tendency to murder,” “the memory of words,” “the sense of sounds; the gift of music,” “the poetical talent,” and “the organ of religion.” fig. 4, fig. 5

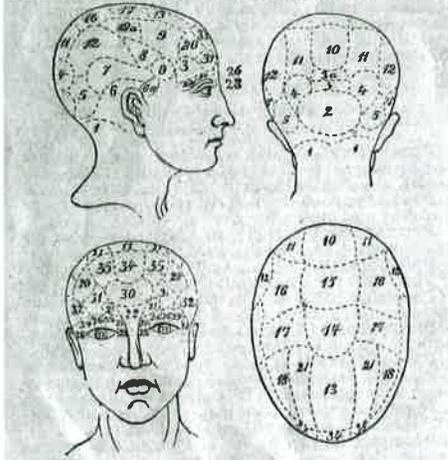


Phrenological Chart of the Faculties.

fig 4

Phrenology diagram, from W. H. De Puy, *People's Cyclopaedia of Universal Knowledge*, 1883

Phre-nol'o-gy (-nôl'ô-jÿ), *n.* [Gr. φρήν, φρενός + -logy.] **1.** Science of the special functions of the several parts of the brain, or of the supposed connection between the faculties of the mind and organs in the brain. **2.** Physiological hypothesis that mental faculties, and traits of character, are shown on the surface of the head or skull; craniology. — **Phre-nol'o-gist**, *n.* — **Phren'o-log'ic** (frên'ô-lôj'ik), **Phren'o-log'ic-al**, *a.*



A Chart of Phrenology.

1. Amativeness ; **2.** Philoprogenitiveness ; **3.** Concentrativeness ; **3 a.** Inhabiteness ; **4.** Adhesiveness ; **5.** Combativeness ; **6.** Destructiveness ; **6 a.** Alimentiveness ; **7.** Secretiveness ; **8.** Acquaintiveness ; **9.** Constructiveness ; **10.** Self-esteem ; **11.** Love of Approbation ; **12.** Cautiousness ; **13.** Benevolence ; **14.** Veneration ; **15.** Firmness ; **16.** Conscientiousness ; **17.** Hope ; **18.** Wonder ; **19.** Ideality ; **19 a.** (Not determined) ; **20.** Wit ; **21.** Imitation ; **22.** Individuality ; **23.** Form ; **24.** Size ; **25.** Weight ; **26.** Coloring ; **27.** Locality ; **28.** Number ; **29.** Order ; **30.** Eventuality ; **31.** Time ; **32.** Tune ; **33.** Language ; **34.** Comparison ; **35.** Causality. [Some raise the number of organs to forty-three.]

fig. 5

The definition of phrenology with corresponding diagram, from Noah Webster, *Webster's Academic Dictionary*, 1895

A century later, as phrenology was already in decline, the work of philosopher Alesha Sivartha captured the pinnacle of this ideology in *The Book of Life: The Spiritual and Physical Constitution of Man* (1912). In this magnificent collection of brain maps and pseudoscientific illustrations, Sivartha explores many of the ideas associated with phrenology, with the brain as the setting for the structuring of all types of social, political, ethical, and cultural concepts. fig. 6, fig. 7, fig. 8

Phrenology was eventually recognized as an extremely flawed system that simply went down in history as a divergent scientific pursuit. It did, however, contribute to a long-lasting meme regarding the modularity of the mind. Many people still think of the brain in terms of left and right, front and back modules, or believe in the presence of a unique centralized control responsible for the great diversity of cognitive tasks and human behaviors. "The idea of a 'centre' for different functions in the brain is so intuitively appealing, it is hard to relinquish," explains renowned neuroscientist Susan Greenfield.¹¹ But it is an inadequate model. Instead of a centralized control, our voluntary and involuntary actions are triggered by a series of electrochemical impulses percolating through millions of neurons, like a multitude of musical instruments coming together for a symphony.

It is estimated that an adult human brain has around one hundred billion neurons, with each neuron being biologically wired to thousands of its neighbors by dendrites and axons. The brain's staggering complexity represents one of the toughest puzzles, challenging modern neuroscientists to constantly reassess their assumptions. One of the men leading this quest is Henry Markram, director of the Center for Neuroscience and Technology at École Polytechnique

Fédérale de Lausanne (EPFL), in Switzerland, and project director of the remarkably impressive Blue Brain project.

Markram and his team of neuroscientists, paired with IBM's sophisticated supercomputer, Blue Gene, are creating a blueprint of the neocortex—a part of the cerebral cortex that accounts for nearly 80 percent of the human brain. fig. 9 In this active region, made up from a dense network of neurons and fibers—commonly known as gray matter due to its gray color in preserved brains—many higher cognitive functions such as conscious thought, memory, and communication occur.

The goal of the Blue Brain project—to generate a holistic model of such an intricate structure—is not a straightforward task and conceivably requires an astounding amount of computing power. This is how writer Jonah Lehrer describes the technical setup behind the project:

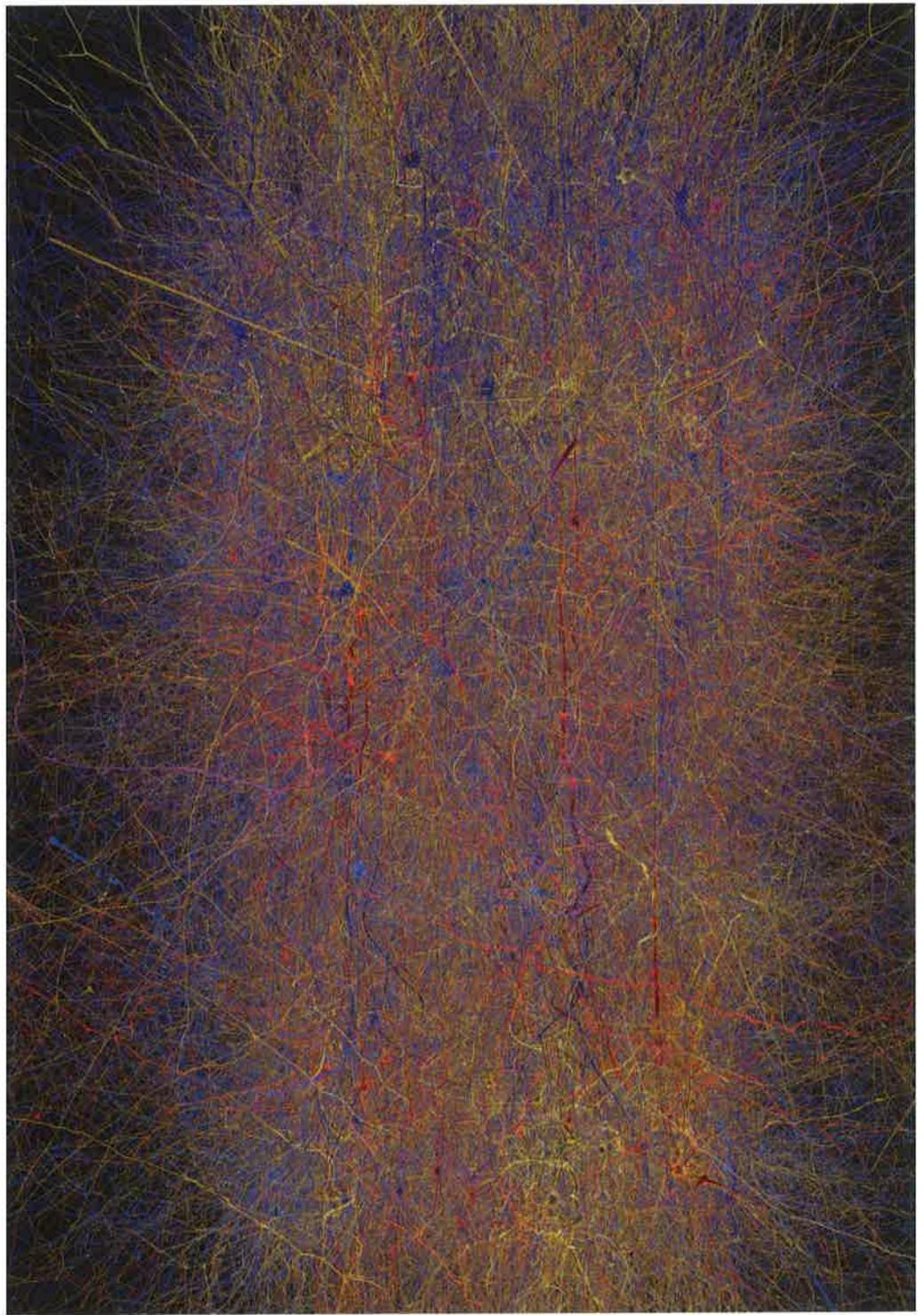
In the basement of a university in Lausanne, Switzerland, sit four black boxes, each about the size of a refrigerator, and filled with 2,000 IBM microchips stacked in repeating rows. Together they form the processing core of a machine that can handle 22.8 trillion operations per second. It contains no moving parts and is eerily silent. When the computer is turned on, the only thing you can hear is the continuous sigh of the massive air conditioner. This is Blue Brain.¹²

Blue Brain is an incredible initiative, only comparable in greatness to the Human Genome Project—an international scientific initiative with the goal of mapping and sequencing the entire human genome. The immense

fig. 9

École Polytechnique Fédérale de
Lausanne, *Blue Brain Project*, 2008

A computer-generated model produced with IBM's Blue Gene supercomputer, part of the Blue Brain project, shows the thirty million connections between ten thousand neurons in a single neocortical column—arguably the most complex part of a mammal's brain. The different colors indicate distinctive levels of electrical activity.



knowledge that could arise from this breakthrough is still hard to grasp, and so are its consequences. Once we have the entire map of the neural circuitry, the possibility of re-creating it in a functional simulation would be the logical next step. In an ambitious statement at the annual TEDGlobal conference in Oxford, England, in July 2009, with the theme "The Substance of Things Not Seen," Markram declared, "It is not impossible to build a human brain and we can do it in ten years."¹³

The first significant milestone of the project has already been achieved: the replication of the neocortical column—a small slice of the brain cortex containing approximately ten thousand neurons, and about thirty million synaptic connections between them. "Now we just have to scale it up," says Markram in his usual optimistic attitude, referring to the replication of the rest of the brain.¹⁴ His encouraging view is founded in the conviction that Blue Brain is conveying a different way of looking at ourselves, and ultimately at science. Markram considers that merely looking at the isolated parts is not providing us the whole picture, and the reductionist approach of neuroscience, successful as it was until now, has exhausted itself. "This doesn't mean we've completed the reductionist project, far from it. There is still so much that we don't know about the brain. But now we have a different, and perhaps even harder, problem. We're literally drowning in data. We have lots of scientists who spend their life working out important details, but we have virtually no idea how all these details connect together. Blue Brain is about showing people the whole."¹⁵

If Markram is right in his conjecture regarding a holistic approach to replace an outmoded reductionist view, then we might see many other areas of science following

this systemic modeling method. What this new reasoning might represent for the advancement of science might be even more significant than Blue Brain itself.

Ubiquitous Datasphere

The internet is one of the most extraordinary and complex systems ever built by man. It has become so influential in our lives that it is easy to forget its relatively young age. In the middle of the Cold War and while working for the U.S. military intelligence agency RAND Corporation to develop a new communication system that could survive a nuclear attack, the then thirty-year-old Paul Baran produced several documents that attested the vulnerabilities of the communication infrastructure of the time. His proposition for a safer alternative would become a central driving force for the subsequent development of the internet. In 1964 Baran suggested three possible models for the novel system: centralized (with a single decision center), decentralized (more than one decision center), and distributed (made by uniformly distributed nodes with no decision center). *fig. 10* Baran recommended the very last one, a model with a noticeable mesh structure, more resilient to an eventual attack. The distributed topology Baran proposed, which he published in a series of reports entitled *On Distributed Communications* (1964), would then be further developed and implemented by another American agency: the Advanced Research Projects Agency, commonly known as ARPA. *fig. 11*, *fig. 12*

Since the first message sent across two computers in October 1969 as a part of the early ARPANET, the internet has grown at an astounding pace. Contemporary maps of the convoluted landscape of routers, servers, and

fig. 10

Paul Baran, Network models, 1964

The three architectures—centralized, decentralized, and distributed—possible for a novel communication system. From Baran, "On Distributed Communications: Introduction to Distributed Communications Networks," 1964 (paper published internally within Rand Corporation).

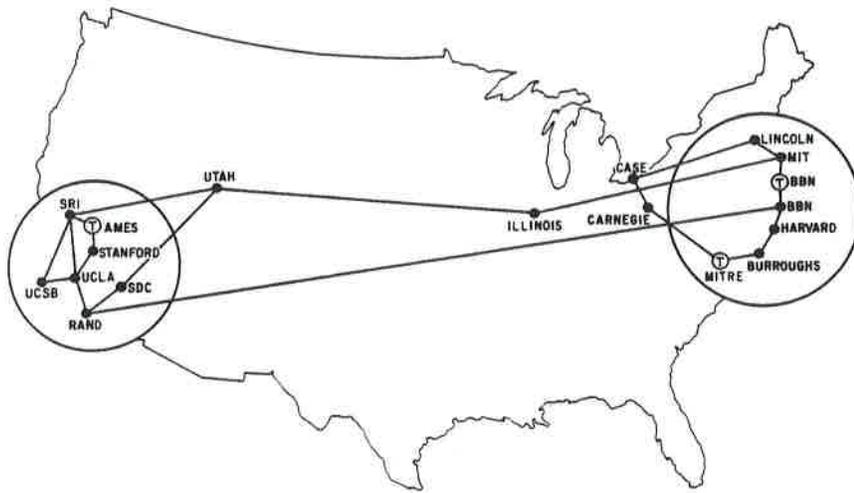
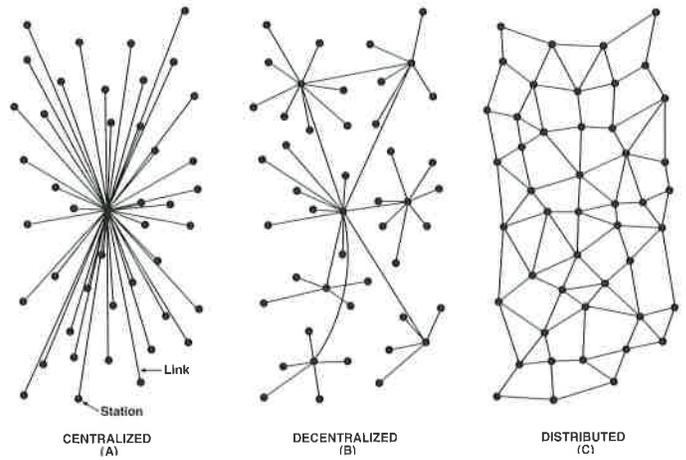


fig. 11

A map of the Advanced Research Projects Agency Network (ARPANET) from September 1971, showing some of its earliest nodes: at University of California, Los Angeles; University of California, Santa Barbara; Rand Corporation; Massachusetts Institute of Technology; and Harvard University. From F. Heart, A. McKenzie, J. McQuillion, and D. Walden, *ARPANET Completion Report*, January 4, 1978.

ARPANET LOGICAL MAP, MARCH 1977

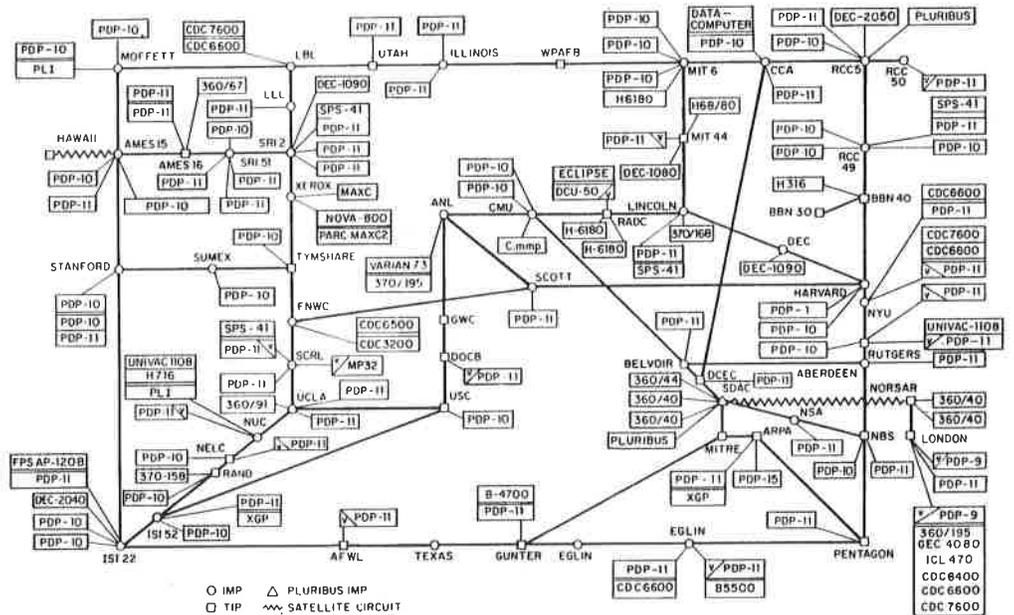


fig. 12

A map of an expanding ARPANET from March 1977. Heart, McKenzie, McQuillion, and Walden, *ARPANET Completion Report*.

(PLEASE NOTE THAT WHILE THIS MAP SHOWS THE HOST POPULATION OF THE NETWORK ACCORDING TO THE BEST INFORMATION OBTAINABLE, NO CLAIM CAN BE MADE FOR ITS ACCURACY)
 NAMES SHOWN ARE IMP NAMES, NOT (NECESSARILY) HOST NAMES

connections are astonishingly complex, highlighting one of the most intricate man-made structures. But one of the most interesting attributes of the internet is that it sustains another equally tangled network of nodes and links, embodying an enormous volume of data: the World Wide Web.

Twenty years after the famous ARPANET experiment, in 1990, English physicist Tim Berners-Lee and Belgian scientist Robert Cailliau, while working for the European Organization for Nuclear Research (CERN) in Geneva, proposed the construction of a "web of nodes" that could store "hypertext pages" visualized by "browsers" in a certain network. The original name for this global hypertext system was "mesh," but in December of the same year, it was launched with its brand new designation: World Wide Web. After the first hypertext pages were added to the web, it was just a matter of time until other websites followed in a vertiginous expansion. In June 1993 there were only about 130 websites in the whole world. By June of 1998 the web had grown to 2,410,067, and by June 2003 there were 40,936,076 indexed websites. Currently the number is greater than two hundred million, and it might be considerably higher, given that many websites include other websites under the same domain, and a remaining number is undocumented and far from the reach of legal estimates.

This proliferation of websites denotes the vitality of the World Wide Web, mostly due to its underlying democratic distribution of information. According to professors of Communication and Creative Arts at Purdue University Calumet Lee Artz and Yahya R. Kamalipour, this massively complex network constitutes an "information biosphere... a single, interconnected information organism of free expression and free trade."¹⁶ fig. 13 But if currently the autonomous web is mostly characterized by the enhanced influence of

common citizens, through the use of empowering online tools and services, the next web revolution will be even more powerful.

While there are millions of information-embedded web pages online, they are, in most cases, unable to automatically extract knowledge from their inherent interconnections. A single neuron is insignificant, but as it communicates with thousands of neighbors through synapses, it suddenly becomes part of a whole, much bigger than the sum of its parts. This whole keeps changing over time by the addition and deletion of nodes, increasing or decreasing the strength of their connections, in order to constantly adapt to human experience and new learning requirements. It is through this process that the brain retrieves an old memory, analyzes the thread of a sudden event, or composes an argument for a particular idea. This is the level of malleability, commonly called neuroplasticity, that the web is expected to develop in the next few years or decades.

It might certainly take longer than that, but there are several signs attesting to this "neurological" transformation of the web. Not only is data becoming more widely accessible—as companies, institutions, and governments open their data sets to the general public—it is also becoming enriched with prolific metadata, allowing new sets of comparison and interweaving. In a March 2009 talk at Technology Entertainment and Design (TED) conference, Berners-Lee made a vehement exaltation for linked data. One year later, in February 2010, he came back to the renowned conference to corroborate his vision with various practical examples, stating that "if people put data on the web—government data, scientific data, community data—whatever it is, it will be used by other people to do wonderful things in ways they never could have imagined."¹⁷

Initiatives such as the U.S. government's launch of Data.gov—an advanced online portal that combines hundreds of databases from a variety of public agencies, institutions, and departments across the country—are a brilliant indicator of change and one that is being replicated the world over. Launched in May 2009, Data.gov opens the door to political transparency and public scrutiny, aiming at a broadly informed democracy, but even more importantly, it adds a very reliable set of building blocks to the growing mesh of online knowledge.

Increasingly distant from any centralized communication model of the past, the significant impending shift of the web will command an even more detailed and tangled layer of complexity, where data becomes widely inter-related with and detached from constraining documents. The early document-centric web will give way to a pulsating ecosystem of data, a truly ubiquitous datasphere, the main challenge of which—apart from privacy concerns—will be interoperability—universal standards and formats that enable an effortless data interlace. The last thing we want is a large collection of indiscernible data points lying in servers across the world. It is particularly interesting to see how the internet's fundamental model of autonomy has been replicated over time, just like looking into a convoluted fractal representation, where the same underlying principle of complexity and interconnectedness is applied to ever more tiny parts of the structure, from routers to servers, web pages, and now data.

Social Collaboration

The idea of social stratification is one of the most ubiquitous and oldest sociological constructs in the world. From feudalism to capitalism, there has always existed rigid layers of society based on social differentiation, with a strong emphasis on the division of labor. It is not only society at large that succumbs to this unyielding model; businesses, armies, churches, governments, and many other entities also follow a defined ranking among their members, always lead by a central commanding figure.

Although it is difficult to define the origins of social stratification, Professor Anthony J. McMichael considers one of the central seeds for its development to have occurred around 10,000 BC in the Fertile Crescent, a bountiful, crescent-shaped area covering parts of the Middle East. The development of agriculture drove modern humans to slowly abandon their nomadic lifestyles for more reliable, confined harvests. This transition from hunting and gathering to settled farming and agriculture gave birth to the first agricultural revolution, known as the Neolithic Revolution. This transformation brought prosperity, the enlargement of rural settlements, and the surge of many new types of labor, which in turn caused the emergence of social class, status, and power—central elements to the emergence of hierarchical systems of domination.

But it was during the Industrial Revolution that many of our hierarchical conceptions of society were widely put into practice. This critical period caused not only a major change in the way cities were planned but also a key transformation in the way businesses and society at large were organized. The fundamental process of rationalization that occurred during this stage became a central impetus for the solidification of bureaucracy, corporate ranking, and



fig. 13

Antonin Rohmer, *Eurosphere*, 2009

A map of the political blogosphere in Central Europe (France, Germany, Italy, and the Netherlands), showing shared links between communities of political bloggers and portals, communities of journalists and experts, communities of political pundits, media websites, trade unions, think tanks, public institutions, NGOs, and activists. The distance between websites, within a community and between communities, reveals the amount of interactions: the closer websites are, the more they engage with each other. The data was collected over a one-year period.

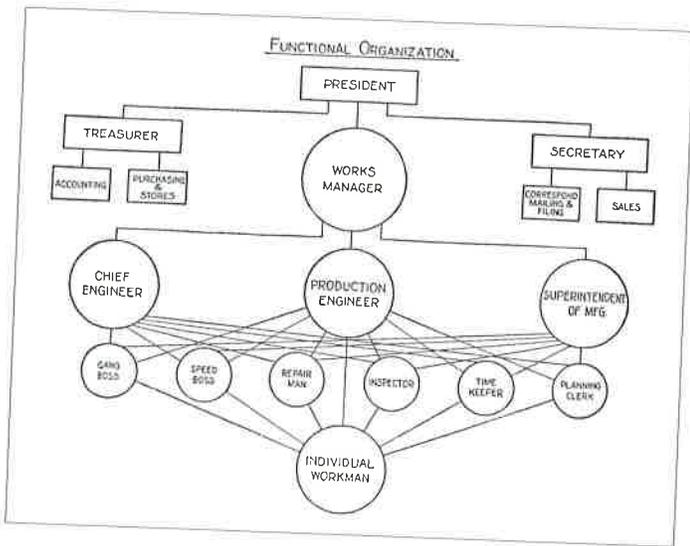


fig. 14

A typical corporate organizational chart, showing the hierarchical structure from the president to the individual workman. From Smith, *Graphic Statistics in Management*.

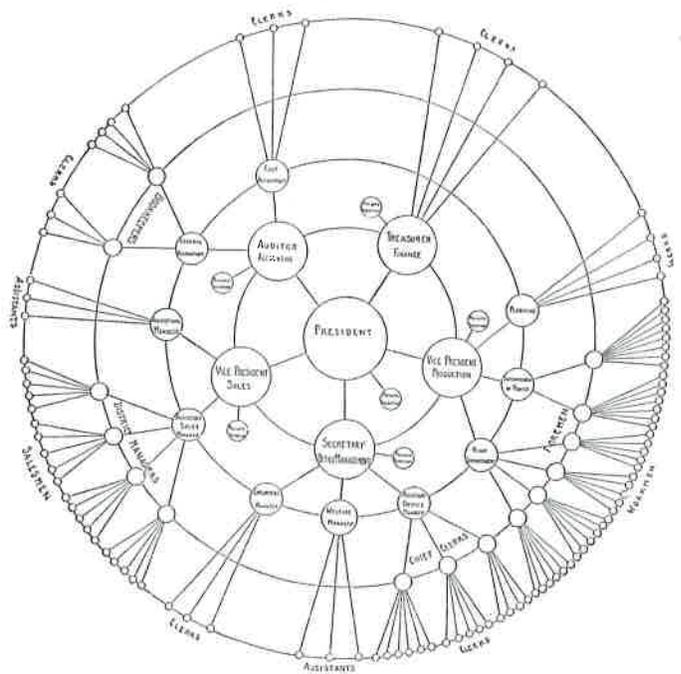


fig. 15

This radial organization chart highlights the centralized decision-making power structure of most companies, with the president at the very core, followed by successive degrees of dependency. From Smith, *Graphic Statistics in Management*.

management models based on centralized control. Many of these ideas are still so ingrained in our modern existence that it is hard to relinquish them. fig. 14, fig. 15

We tend to consider social hierarchy as the norm across societies and, in some cases, as a necessity or sociological predisposition. But in fact, many past and present-day hunter-gatherer societies have little or no concept of economic or political status, class, or permanent leadership. Many indigenous communities in the Americas and Australia today follow the same type of decentralized and egalitarian structure, since stratification is broadly seen as a cause of conflict and instability.

In *The Starfish and the Spider* (2006), Ori Brafman and Road Beckstrom describe the difficulties encountered by the Spanish conquistadors when facing the leaderless Apache tribes in the sixteenth century in present-day New Mexico. The Spanish tried to convert them to Christianity and to a sedentary agrarian lifestyle, but the Apache resisted and fought back and held them off for two centuries. "It wasn't that the Apaches had some secret weapon that was unknown to the Incas and the Aztecs. Nor had the Spanish army lost its might," explain the authors. "No, the Apache defeat of the Spanish was all about the way the Apaches were organized as a society"—a simple, yet complex flattened layout, typical of a decentralized configuration.¹⁸

Decentralized social structures do not have a leader in control or defined ranks, and most importantly, they have no headquarters. Additionally, when attacked, centralized systems tend to become even more centralized, while decentralized organizations become more open and decentralized. Even when the Spanish went after and started killing Nant'ans (a type of spiritual leader), new Nant'ans

would immediately emerge. The further the Spanish charged, the more decentralized and hard to conquer the Apaches became.

This particular chapter of history is not entirely distant from present-day news headlines announcing the state of affairs between armies and terrorist cells. Although with an entirely distinct nature and political motivation, the main tool of terrorist resistance today is the same as the one perpetrated by the Apache four hundred years ago: decentralization.

Decentralized social groups are not only common in hunter-gatherers and terrorist networks, but continue to grow today, more than in any other period since the Industrial Revolution, challenging many secular theories and also becoming intrinsically associated with our technological progress. As Don Tapscott and Anthony D. Williams affirm in their bestselling *Wikinomics* (2006), "Profound changes in the nature of technology, demographics, and the global economy are giving rise to powerful new models of production based on community, collaboration, and self-organization rather than on hierarchy and control."¹⁹ *Wikinomics* is just one of many books published in the last few years exploring the topic of decentralization and its effects on modern society. Much has been written, blogged, and discussed on the evolution of this new nonstratified scheme, usually coupled with encouraging democratized ideas such as the wisdom of crowds, democratic journalism, local decision, self-empowerment, independence, and self-organization, and repeatedly illustrated by its main frontrunners: Wikipedia, the open-source movement, Craigslist, and Digg.

As the web is a prime case of a leaderless structure, embodied by its overlaying mesh of self-governing information



fig. 16

Linkfluence, *CPAN Explorer*, 2009

A map showing the collaborations between the most active Perl programming language developers within the large online community CPAN (Comprehensive Perl Archive Network). The size of the node denotes the number of Perl modules (discrete components of software for the Perl programming language) an author has

released on CPAN, and connections represent shared modules between authors.

nodes, it is not surprising that the most well-known cases of decentralization are happening on the web. This growing autonomy is also fomenting a critical social behavior that sustains many online services and initiatives. In Thomas L. Friedman's international bestselling book *The World is Flat* (2005), he describes ten "flatteners"—key drivers for transforming the world into a level playing field. Among them is what Friedman considers to be the most subversive force of all: online collaboration. fig. 16

When geography and the speed of communication are no longer obstacles, collaboration is virtually unlimited. The web is not only a data biosphere but also a social biosphere with access to an increasingly diverse set of online communication tools that are environments for globalized collaboration and community building. As professor of new media Geert Lovink eloquently states, "What defines the Internet is its social architecture. It's the living environment that counts, the live interaction, not just the storage and retrieval procedure."²⁰

As the intricacy of online social network services and their inherent collaboration increases, so does the prospect of a human collective intelligence, a sphere of human thought, or "noosphere," as it was famously called by Russian mineralogist and geochemist Vladimir Vernadsky. In fact, the image of someone closing their laptop and turning off their online status is quickly becoming an illustration of the past, as the virtual web becomes more and more intertwined with real life. As it continues to expand and pervade every level of human activity, the web also diffuses many of its collaborative social models based on decentralization and democratization, and the effects of this conceptual permeation might create an everlasting shift in the stratification of society.

Classifying Information

The need to store and organize information has been with us since early Sumerian times, but it is from medieval Europe that we have the most vivid ancient accounts. In the twelfth century, the emergence of universities marked the decline of the great cloister libraries and the rise of a new form of knowledge archive: the university library. As these new centers of scholarly teaching and research became increasingly independent from religion, they expanded their curricula to include secular disciplines, propelling an exuberant intellectual activity and an intense eagerness for even more knowledge—in the form of books. This fervor was soon met with an increase in book production, aided by the invention of printing and cheaper paper. fig. 17

The insatiability for information led to challenges in indexing many of the newly discovered works. Professor Alfred W. Crosby explains in *The Measure of Reality* (1996) how medieval schoolmen "were at loss for a principle by which to arrange masses of information for easy retrieval."²¹ Alternative categorization systems had to be devised, with many new indices featuring Arabic numerals, which had just started to disseminate across Europe. Strangely enough, one of the solutions to the dilemma, just before the use of alphabetization became standard in the twelfth century, was quite distinct from most modern objective taxonomies. Looking at the arrangement of information through a subjective lens, medieval schoolmen organized library catalogs by order of prestige, beginning with the Bible, followed by books on and by the church fathers (influential theologians, Christian teachers, and bishops), and so on, with books on liberal arts coming last.²²

Many generations later, on the other side of the ocean, American librarian Melvil Dewey (1851–1931)

devised one of the most relevant contributions to knowledge organization. Created in 1876, the Dewey Decimal Classification (DDC) method is a widely used library classification system based on decimal numbers. Having undergone twenty-two major revisions, the last one in 2004, its uncomplicated structure has been adopted by innumerable libraries, both in the United States and abroad.

As the founder of the American Metric Bureau—an organization established in Boston in 1876 with the goal of promoting the metric system in the United States—Dewey was a passionate supporter of the decimal system of measurement first adopted by France, which in part explains his preference for the inherent simplicity of powers of ten. The system he created organizes all knowledge into ten classes (e.g., Religion [100], Social Sciences [200], and Literature [800]). These classes are subdivided into ten divisions, and each division into ten sections. *fig. 18* To locate a particular book on ecology, one would start on Science (500), then Life Sciences (570), and finally Ecology (577). In comparison, that same book on ecology would have a call number QH540-549.5 under DDC's main competitor, the Library of Congress Classification (LCC) system. The unclutteredness of the purely numerical method was an important reason for its widespread adoption, but even though the simplest of its kind, DDC is still based on an absolute tree arrangement of fixed positions, allowing for few, if any, interlinks. Other methods have challenged Dewey's structure, some using the notion of faceted classification, which is based on calling out clearly defined properties of a book (e.g., title, author, subject, year). But "both trees and faceted systems specify the categories, or facets, ahead of time," explains technologist, writer, and philosopher David Weinberger. "They both present users with tree-like structures

for navigation, letting us climb down branches to get to the leaf we're looking for."²³ More recently a new method has emerged that promises to cut across the branches and reach forthwith for the leaves.

Initially used in online services such as Flickr, Del.icio.us, and YouTube, folksonomy is a method employed by thousands of websites, services, and applications. A term coined by information architect Thomas Vander Wal in July 2004, *folksonomy* is a portmanteau of *folk* and *taxonomy*, and is also known as social classification or social tagging. Folksonomy is an alternative system for categorizing content by means of informal tags—specific keywords assigned to a piece of information (e.g., a web page, video, image, computer file)—which describe the item and facilitate its retrieval during browsing or searching. This emergent bottom-up classification is intrinsically distinct from top-down hierarchies like the Dewey system. In DDC, each book or document has a unique reference in a single immutable hierarchical structure. In contrast, any digital object created by folksonomy is defined by different tags (metadata), allowing it to be ordered and located in multiple ways. It is also a highly adaptable method, since it ultimately relies on the natural language of the community or individual using it. *fig. 19*

In an interesting reference to this phenomenon, David Weinberger, who has been following this change up close, states: "Autumn has come to the forest of knowledge, thanks to the digital revolution. The leaves are falling and the trees are looking bare. We are discovering that traditional knowledge hierarchies that have served us so well are unnecessarily restricted when it comes to organizing information in the digital world."²⁴ According to Weinberger, while the old method conceived immutable

fig. 17

Jan Cornelius Woodanus, *Leiden University Library*, 1610

This renowned print depicts the organization of shelves at the library of the University of Leiden, the oldest university in the Netherlands, founded in 1575.



500 Science	600 Technology	900 History and Geography
570 Life Sciences	610 Medical Sciences	970 General history of North America
572 Biochemistry	613 Promotion of Health	973 General history of United States
572.8 Biochemical Genetics	613.2 Dietetics	973.9 Twentieth Century
572.86 DNA (Deoxyribonucleic acid)	613.24 Weight-gaining diet	973.91 1901-1953

fig. 18 (above)

The hierarchical structure of the Dewey Decimal Classification system, showing three individual paths within the Sciences (500), Technology (600), and History and Geography (900) categories

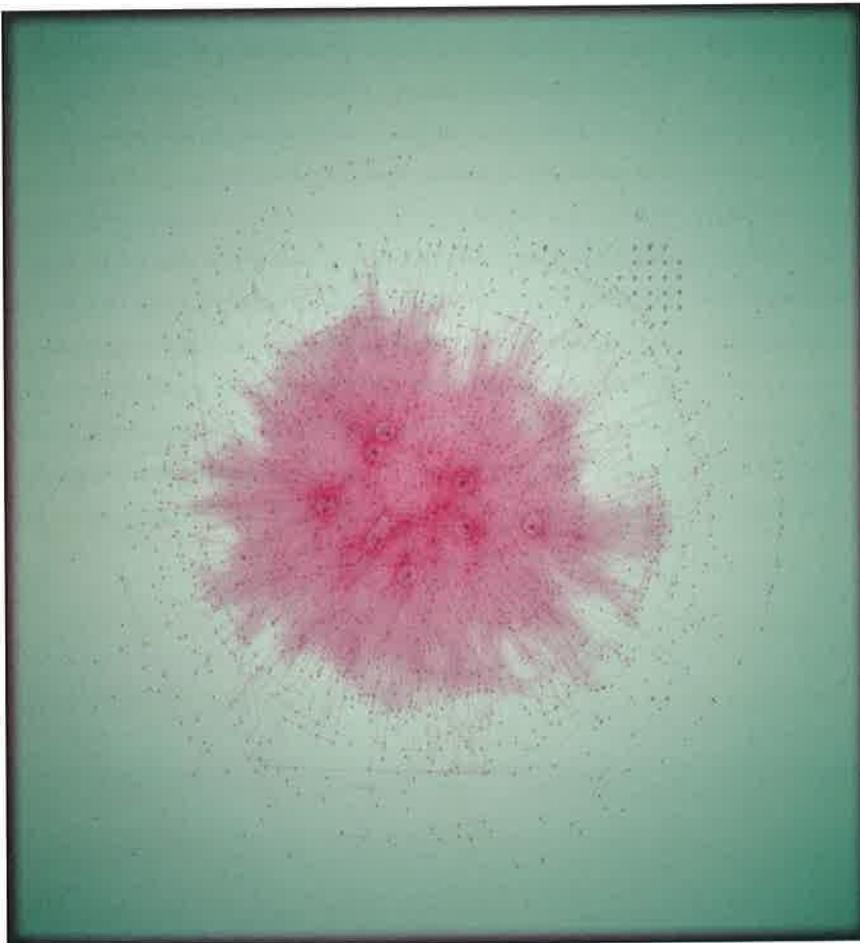


fig. 19 (left)

Kunal Anand, *looks delicious*, 2008

An intricate graph of tag relationships in an individual's Del.icio.us account, a pioneer social-bookmarking system and one of the precursors of folksonomy

trees, the new creates “piles of leaves” in an idiosyncratic, flexible way.

The adoption of folksonomy would certainly have been much less likely if not for the significant advances in modern computer science, particularly in search algorithms and data mining. In the past it would have been unthinkable to conceive a folksonomic model without an advanced computerized system that could facilitate the simultaneous search and retrieval of thousands of items. Recent progress has also placed folksonomy in the midst of a much larger technological movement—influenced by parallel advances in tracking and navigation satellite systems, microchip implants, and radio-frequency identifiers—that aims at converting a variety of objects (physical or digital) into intelligible, reachable, and indexable entities.

It is still too early to speculate on the role of folksonomy in the next few years or decades, and some might even say that it will never be as dominant as it promises. One of these hushing voices is renowned information architect Peter Morville, who considers the revolutionary rhetoric of the free-tagging movement behind folksonomy to be an overhyped exaggeration. Although acknowledging the benefits of folksonomy as a trendspotting and personal bookmarking tool, Morville says in his book *Ambient Findability* (2005) that when it comes to findability, folksonomies’ “inability to handle equivalence, hierarchy, and other semantic relationships causes them to fail miserably at any significant scale.... If forced to choose between the old and new, I’ll take the ancient tree of knowledge over the transient leaves of popularity any day.”²⁵

Whatever your view on the topic, one thing is indubitable: this innovative system has brought a new agility and malleability to the way we index and access information,

possibly causing an important shift in the long run. Will folksonomy be a point of departure for profound structural change or a mere fad portrayed in history as a transitory alternative to the hierarchical tree model? Only time will tell.

Ordering Nature

Our long obsession for orderly arrangement can be best observed in the keystone of science: the classification of the natural world. As in the establishment of knowledge classification, we turn to Aristotle for the first proposal on the division of living things as a linear gradation principle. The most well-known student of Plato and the teacher of Alexander the Great, Aristotle was highly dedicated to the tangible world. His views on the physical sciences, published as a collection of treatises in his seminal *Physica* (Physics) (ca. 350 BC), have been a key influence in medieval erudition and an impetus for many radical views leading to the Scientific Revolution. Aristotle’s conception of a “natural philosophy,” dedicated to the uncovering of natural phenomena, was the precursor of the natural sciences and the dominant term referring to scientific inquiry before the emergence of modern science.

Both Plato and Aristotle believed in universalism (a school of thought that believes in universal facts or properties), but while Plato contemplated the universal apart from particular things—since the particular was merely a prototype or imitation of an ideal form—Aristotle saw the universal in particular things, in what he considered to be the essence of things. His belief in essentialism—the presence of an immutable essence in every object—led to the desire for an absolute ordering of nature, a perfect universe, where all species are hierarchically arranged

in a natural ladder from lowest to highest. Even though some of the classes and divisions he set forth in *Historia Animalium* (History of animals), published circa 350 BC, quickly became obsolete, others, such as genus, species, and substance, have endured for a long time and still resonate in modern natural taxonomies.

Throughout the Middle Ages, many of Aristotle's ideas were revived, expanded, and sometimes misrepresented. *Scala naturae* (natural ladder), commonly referred to as the Great Chain of Being, was a medieval philosophical concept that viewed the world as a hierarchical tree of virtues, which assessed the most heavenly virtues of all matter and life on the planet. Different versions of this partisan system have been developed over the centuries, highlighting particular beliefs or ideologies of the time. Some placed God in the very pinnacle of the hierarchy, with angels immediately below, followed by members of the church, laymen, animals, and plants, until the very last foundational layer, earth itself. Other variations, based on the Divine Right of Kings—a doctrine of royal absolutism in which the monarch is subject to no earthly authority—positioned the king at the very top of the ladder, above the aristocratic lords, with the peasants below them. Applicable in limitless circumstances, *scala naturae* was always portrayed as an immutable linear gradation of perfection, or heavenly virtue.

The Renaissance gave rise to serious efforts to categorize a growing number of unidentified species, particularly through the work of naturalists and physicians, including Conrad von Gesner, Andrea Cesalpino, Robert Hooke, John Ray, Augustus Rivinus, and Joseph Pitton de Tournefort. But one of the greatest contributions to biological classification and nomenclature came a bit later, by

Swedish physician and zoologist Carl Linnaeus (1707–1778). The Linnaean taxonomy, as it was later called, was set forth in his *Systema naturae* (1735) and organized nature into three main kingdoms: *Regnum animale* (animal), *Regnum vegetabile* (vegetable), and *Regnum lapideum* (mineral). Based on a nested hierarchy of successive categories, or ranks, kingdoms were divided into classes, and classes were divided into orders, and so on, until the very last rank. Organisms were essentially grouped by their shared physical traits, and many were kept in similar arrangements until modern times. fig. 20

With the recognition of Darwin's theory of evolution as the central principle for species formation, Linnaeus's classification somewhat fell out of favor. This is where phylogenetics came in. Seen as "the history of the descendants of living beings," or the study of evolutionary association across different groups of organisms, phylogenetics is a contemporary by-product of Darwin's drastic biological revolution, which greatly informed the naming and classification of species.²⁶ Central to its study is the Phylogenetic tree—a hierarchical representation of evolutionary relationships between ranges of biological species that share a common ancestor. Darwin himself suggested such an evolutionary tree, in a rough sketch back in 1837. fig. 21 Years later his tree concept would be materialized in his seminal *On the Origin of Species by Means of Natural Selection* (1859). The only illustration in this masterpiece appears in the fourth chapter, "Natural Selection," in what he denominated the *Tree of Life*. Further in the chapter's summary, Darwin expands on the tree metaphor to better explain his views on evolution:

fig. 20

The taxonomic ranks of the fruit fly, the modern human, and the pea, in a hierarchical tree according to Linnaean taxonomy

	Fruit fly	Human	Pea
Domain	Eukarya	Eukarya	Eukarya
Kingdom	Animalia	Animalia	Plantae
Phylum	Arthropoda	Chordata	Magnoliophyta
Subphylum	Hexapoda	Vertebrata	Magnoliophytina
Class	Insecta	Mammalia	Magnoliopsida
Subclass	Pterygota	Theria	Rosidae
Order	Diptera	Primates	Fabales
Suborder	Brachycera	Haplorrhini	Fabineae
Family	Drosophilidae	Hominidae	Fabaceae
Subfamily	Drosophilinae	Homininae	Faboideae
Genus	Drosophila	Homo	Pisum
Species	<i>D. melanogaster</i>	<i>H. sapiens</i>	<i>P. sativum</i>



fig. 21

A diagram of an evolutionary tree, from Charles Darwin, *First Notebook on Transmutation of Species*, 1837

This simple sketch alludes to the branching of lineages, similar to the splitting of a tree's trunk, and marks the first-known representation of an evolutionary tree. Above the sketch, Darwin wrote, "I think."

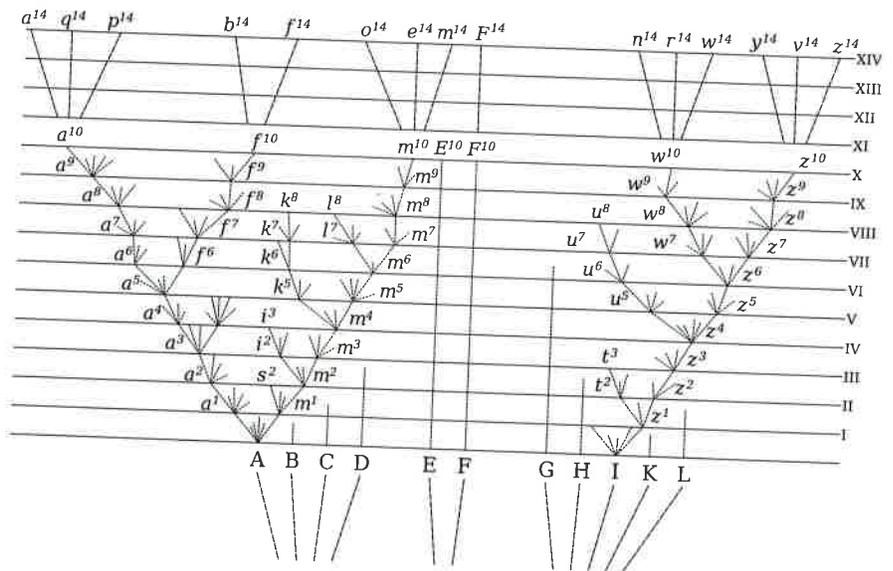


fig. 22

Tree of life, from Charles Darwin, *The Origin of Species*, 1859

This illustration, the only one featured in the first edition of Darwin's masterpiece, popularized the notion of the evolutionary tree and later catalyzed the field of phylogenetics.

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. The green and budding twigs may represent existing species; and those produced during former years may represent the long succession of extinct species. At each period of growth all the growing twigs have tried to branch out on all sides, and to overtop and kill the surrounding twigs and branches, in the same manner as species and groups of species have at all times overmastered other species in the great battle for life.²⁷

Darwin was well aware of the importance of the tree schema and considered it at the core of his thinking. In a letter to his publisher John Murray, sent on May 31, 1859, a few months before the publication of his scientific landmark, Darwin writes: "Enclosed is the Diagram which I wish engraved on Copper on *folding* out Plate to face latter part of volume.—It is an odd looking affair, but is *indispensable* to show the nature of the very complex affinities of past & present animals."²⁸ This indispensable illustration is, according to Darwin, not a secondary element to his narrative but a crucial symbol of his idea. *fig. 22*

The notion of a tree as a classification system was nothing new and neither was its applicability to the organization of species. We had seen it before in the Great Chain of Being, and much of the work developed by Aristotle, Leibniz, and Linnaeus. *fig. 23* However, Darwin introduced a critical unsettling element to the equation: time. Darwin's evolutionary tree was no longer a static immutable image of the present but a shifting dynamic model, encompassing

years and years of change and adaptation. This genealogical variable, however, brought a big dilemma to biological sciences, as Sigrid Weigel points out in her brilliant "Genealogy: On the Iconography and Rhetorics of an Epistemological Topos." Biologists had to not only strive for the constancy required in a classification system agreed by all but also embrace variation and modification as part of evolutionary change. This was understandably a cumbersome endeavor.

The continuous challenge of combining uniformity and variety in an integrated model has recently suffered a major quiver, with scientists having to rethink their approach to phylogenetics. The first significant change is technical and relates to new methods of analysis. While most early evolutionary trees were based on morphological attributes (appearance and physical traits), the more recent trees are constructed using molecular data (based on genetic and molecular sequencing). By providing an alternative way of looking at the shared relationships between species, this approach has introduced uncertainty to established labeling conventions. The second, and the most current, upheaval runs much deeper and has caused a major shift in the way we conceive the classification of biodiversity.

In June 2005 a group of researchers from the Computational Genomics Group at the European Bioinformatics Institute (EBI) published an influential paper entitled "The Net of Life: Reconstructing the Microbial Phylogenetic Network." In this study, the EBI team, lead by Christos Ouzounis, set up a new vision for evolution classification based on networks, rather than trees, in which "the genomic history of most microbial species is a mosaic, with a significant amount of horizontal gene transfer present."²⁹

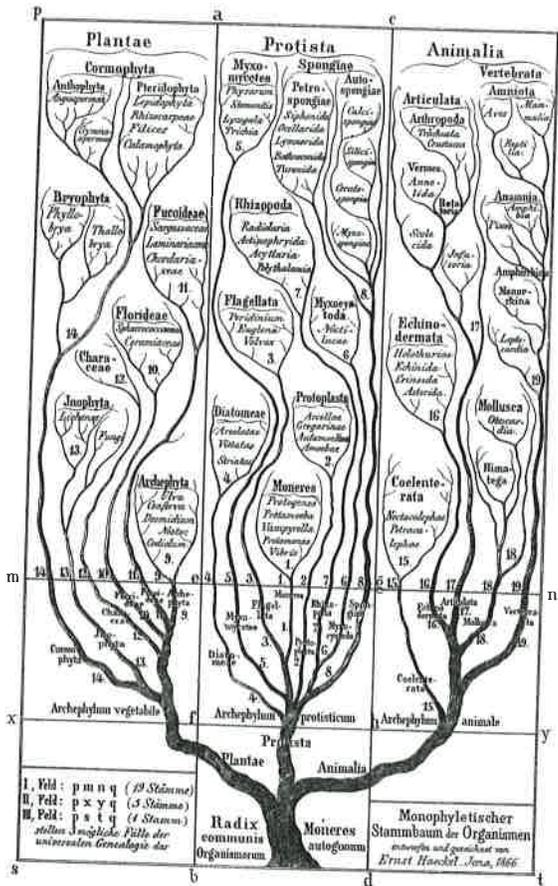
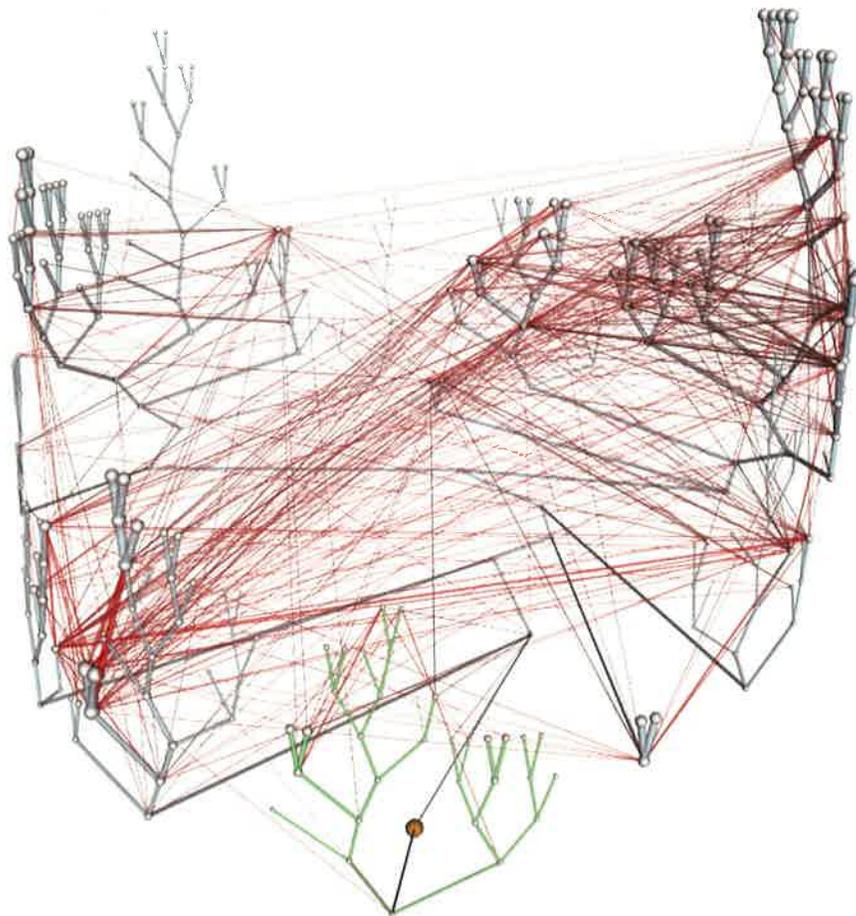


fig. 23

A diagram of the tree of life. From Ernst Haeckel, *Generelle morphologie der organismen* (General morphology of organisms), 1866.

fig. 24

A three-dimensional representation of the net of life—an alternative version to the common tree of life. Red lines, depicting horizontal gene transfer, lie individual bacteria and archaea, which all originate from a common root depicted in orange. From V. Kunin, L. Goldovsky, N. Darzentas, and C. A. Ouzounis, "The Net of Life: Reconstructing the Microbial Phylogenetic Network," *Genome Research* 15, no. 7 (July 2005): 954–59.



Horizontal gene transfer (HGT) is a recurrent process in nature and occurs when a living being incorporates genetic material from a different organism without being its offspring. As a prevailing form of genetic transfer in single-celled organisms, such as bacteria, HGT is the subject of much debate and study. Since roughly 90 percent of the cells in the human body are nonhuman organisms—essentially bacteria—the impact of these studies in future assessments of evolutionary processes is monumental.

Phylogenetics, therefore, is in the midst of a reconstruction phase in which there is a vertical disintegration of the tree of life. According to biologist Johann Peter Gogarten, “the original metaphor of a tree no longer fits the data from recent genome research.”³⁰ He also suggests that biologists “use the metaphor of a mosaic to describe the different histories combined in individual genomes and use the metaphor of a net to visualize the rich exchange and cooperative effects of HGT among microbes.”³¹

In the study conducted by EBI, an arresting image was produced showing a hybrid between the original tree of life and the new HGT mesh. In this model the various horizontal links, or “vines,” cross the tree in a form of rhizomatic contamination. *fig. 24* Based on these remarkable advancements, an international set of rules for phylogenetic nomenclature, called the PhyloCode, is currently being devised by the International Society for Phylogenetic Nomenclature. This considerable effort might well be the basis for a new shift in species classification, soon replacing the old tree metaphor with a novel network representation: the net of life.

Network Thinking

In the various cases explored throughout this chapter, we saw how previous conceptions based on hierarchical and centralized tree organizations are giving way to new ideas that are able to address the inherent complexities of modern society. Cities, the brain, the World Wide Web, social groups, knowledge classification, and the genetic association between species all refer to complex systems defined by a large number of interconnected elements, normally taking the shape of a network. This ubiquitous topology, prevalent in a wide range of domains, is at the forefront of a new scientific awareness of complexity, epitomizing the third stage of science described by Weaver. Networks are not just an omnipresent structure but also a symbol of autonomy, flexibility, collaboration, diversity, and multiplicity. As nonhierarchical models, networks are embedded with processes of democratization that stimulate individuality and our appetites for learning, evolving, and communicating. They are, in essence, the fabric of life.

However, even though a significant transition from trees to networks has occurred in a variety of fields, the two models are not necessarily conflicting. “There are knots of arborescence in rhizomes, and rhizomatic offshoots in roots,” proclaim Deleuze and Guattari with respect to this occasional overlap.³² In some of the aforementioned cases, network thinking denotes an alternative and possibly complementary view of the analyzed system; in others, it embodies a drastic departure from the existing *modus operandi*.

In order to tackle problems of an increasingly complex and interconnected nature, we need to consider new methods of analysis, modeling, and simulation. More importantly, we need to consider an alternative way of

thinking. We act and live in networks, so it makes sense that we start thinking in networks. fig. 25 By truly embracing network thinking we can not only dissect a variety of interdependent natural systems, including our own brain, but also apply the same knowledge in the development of future endeavors. In reference to the challenge of social networks, leading social scientist Jacob Moreno stated back in 1933 that “until we have at least determined the nature of these fundamental structures which form the networks, we are working blindly in a hit-or-miss effort to solve problems.”³³ The global effort of constructing a general theory of complexity is tremendous and may lead to major improvements in health, stability, and security of most systems around us. As physicist and complex-network expert Albert-László Barabási declares in *Linked* (2003): “Once we stumble across the right vision of complexity, it will take little to bring it to fruition. When that will happen is one of the mysteries that keeps many of us going.”³⁴

fig. 25

A partial food web, depicting predator-prey relationships between species at the Scotian Shelf in the Northwest Atlantic off of the east coast of Canada. Species names enclosed in rectangles are of those exploited by humans, with cod at the heart of the convoluted network. Despite its remarkable intricacy, this food web is incomplete, because the feeding habits of all participants have not been

fully described. Furthermore, not all species—including some of the marine mammals—spend the entire year in the area.

Notes

- 1 Lecointre and Le Guyader, *The Tree of Life*, 17.
- 2 Ibid., 21.
- 3 Ibid.
- 4 Ibid.
- 5 Alexander, “A City is Not a Tree.”
- 6 Ibid.
- 7 Ibid.
- 8 Ibid.
- 9 Jacobs, *The Death and Life of Great American Cities*, 3.
- 10 Ibid., 433.
- 11 Greenfield, *The Human Brain*, 53.
- 12 Lehrer, “Out of the Blue.”
- 13 Fildes, “Artificial brain ‘10 years away.’”
- 14 Lehrer, “Out of the Blue.”
- 15 Ibid.
- 16 Artz and Kamalipour, *The Globalization of Corporate Media Hegemony*, 118.
- 17 Berners-Lee, “Tim Berners-Lee.”
- 18 Bratman, *The Starfish and the Spider*, 18.
- 19 Tapscott and Williams, *Wikinomics*, 1.
- 20 Lovink, *The Principle of Networking*, 11.
- 21 Crosby, *The Measure of Reality*, 63.
- 22 Ibid.
- 23 Ibid.
- 24 Ibid.
- 25 Morville, *Ambient Findability*, 139.
- 26 Lecointre and Le Guyader, *The Tree of Life*, 5.
- 27 Darwin, *The Origin of Species*, 171.
- 28 Darwin Correspondence Project Database.
- 29 Ibid.
- 30 Gogarten, “Horizontal Gene Transfer.”
- 31 Ibid.
- 32 Deleuze and Guattari, *A Thousand Plateaus*, 20.
- 33 *New York Times*, “Emotions Mapped by New Geography.”
- 34 Barabási, *Linked*, 238.