

Conceptions of a Global Brain: an historical review

Francis HEYLIGHEN

CLEA, Free University of Brussels, Pleinlaan 2, B-1050 Brussels, Belgium

<http://pcp.vub.ac.be/HEYL.html>

ABSTRACT. The "global brain" is a metaphor for the intelligent network formed by the people of this planet together with the knowledge and communication technologies that connect them together. The different approaches leading up to this conception, by authors such as Spencer, Otlet, Wells, Teilhard, Russell and Turchin, are reviewed in their historical order. The contributions are classified in three major approaches: organicism, which sees society or the planet as a living system; encyclopedism, which aims to develop a universal knowledge network; and emergentism, which anticipates the evolution of a suprahuman level of consciousness. The shortcomings of each perspective lead us to propose an integrated approach, based on evolutionary cybernetics. Its selectionist logic allows us to analyse the process whereby initially selfish individuals self-organize into a synergetic system functioning at a higher level of intelligence, making use of an advanced version of the world-wide web.

Keywords: global brain, world-wide web, organicism, encyclopedism, emergentism, cybernetics, evolution.

1. Introduction

There is little doubt that the most important technological, economic and social development of the past decade is the emergence of a global computer-based communication network. This network has been growing at an explosive rate, affecting—directly or indirectly—ever more aspects of the daily lives of the people on this planet. A general trend is that the information network becomes ever more global, more encompassing, more tightly linked to the individuals and groups that use it, and more intelligent in the way it supports them. The web doesn't just passively provide information, it now also actively alerts and guides people to the best options for them personally. To support this, the web increasingly builds on the knowledge and intelligence of all its users and information providers collectively, thanks to technologies such as collaborative filtering, agents, and online markets. It appears as though the net is turning into a nervous system for humanity.

The "Global Brain" (GB) is a metaphor for this emerging, collectively intelligent network that is formed by the people of this planet together with the computers, knowledge bases, and communication links that connect them together [1]. This network is an immensely complex, self-organizing system. It not only processes information, but increasingly can be seen to play the role of a brain: making decisions, solving problems, learning new connections, and discovering new ideas. No individual, organization or computer is in control of this system: its knowledge and intelligence are distributed over all its components. They emerge from the collective interactions between all the human and machine subsystems. Such a system may be able to tackle current and emerging global problems that have eluded more traditional approaches. Yet, at the same time it will create new technological and social challenges which are still difficult to imagine.

Although these developments seem very modern, the underlying visions of knowledge and society have deep roots, going back to Antiquity, and developed in particular during the 19th and 20th centuries. The present paper wishes to review the main conceptual developments in an approximately historical order. The GB is a complex and multifaceted idea, which has been proposed independently under many different names and guises. I will try to classify the major contributions according to their guiding metaphor or source of inspiration. This produces three major categories, that I will label as *organicist*, *encyclopedist* and *emergentist*, depending on whether they see the GB as a social organism, a universal knowledge system, or an emergent level of consciousness. I will conclude by sketching an approach that attempts to integrate the preceding conceptualizations, using evolutionary and cybernetic theories to go beyond metaphors and build a scientific model that can be operationalized and applied to practical problems.

Organicism: society as a living system

It is an old idea that society is in many respects similar to an organism or living system. In this metaphor, organizations or institutions play the role of organs, each performing its particular function in keeping the system alive. For example, industrial plants extract energy and building blocks from raw materials, just like the digestive system, while roads, railways and waterways transport these products from one part of the system to another one, just like the arteries and veins. This metaphor can be traced back at least as far as Aristotle [2]. In the 19th century, it was a major inspiration for the founding fathers of sociology, such as Comte, Durkheim and particularly Spencer.

The British philosopher Herbert Spencer based his *Principles of Sociology* (1876) [3] on the postulate that "society is an organism", pointing out the many analogies between structures and functions, while emphasizing the internal processes of integration and differentiation (division of labor):

A social organism is like an individual organism in these essential traits: that it grows; that while growing it becomes more complex; that while becoming more complex, its parts acquire increasing mutual dependence; that its life is immense in length compared with the lives of its component units; that in both cases there is increasing integration accompanied by increasing heterogeneity.

However, according to Spencer this analogy does not extend to the mental functions:

the discreteness of a social organism ... does prevent that differentiation by which one part becomes an organ of feeling and thought, while other parts become insensitive. High animals [on the other hand] ... are distinguished ... by complex and well integrated nervous systems. ... Hence, then, a cardinal difference in the two kinds of organisms. In the one, consciousness is concentrated in a small part of the aggregate. In the other, it is diffused throughout the aggregate

He went on to note that the consciousness or nervous system of society is reflected in its democratic institutions and government, but, lacking the concept of a global information network, fell short of uncovering any brain-like structure.

After its popularity around the beginning of the 20th century, organicism (and the ensuing structural-functionalism) has lost most of its appeal to sociologists. The idea that society forms an integrated, self-maintaining whole, where every individual or group performs its function, has often been used to justify a status quo, and thus counter any protest against the ruling classes. For example, the Roman consul Menenius Agrippa appeased the Plebeians by arguing that the hands should not rebel against the other organs because otherwise the entire body would be destroyed [4]. Since Marx, sociologists and political scientists have been more interested in how society can be

changed, and how the oppressed can be liberated. This entails a focus on the unavoidable conflicts and competition within society, in contrast to the organicist approach which emphasizes synergy and cooperation. The organicist view is not just rejected on the left by Marxists, but on the right by advocates of "laissez-faire" economics, who abhor the idea of individuals as merely little cells subordinated to a collective, which they see as a justification for totalitarian systems such as those created by Mao, Hitler or Stalin (although a more up-to-date view comes to the opposite conclusion, namely that a more "organic" society would increase individual freedom and diversity [⁵]).

Outside of sociology, the organicist view has regained in popularity with a deeper understanding of living systems and the growing awareness of the world as an interdependent whole. Space travel has made an important contribution to this shift of perspective: while we can see society only from the inside, and therefore tend to focus on the differences and oppositions between its parts, satellites and astronauts brought back pictures of the Earth viewed from the outside, thus focusing our attention on the coherence of the whole. The futurologist and systems theorist Joël de Rosnay has turned this perspective into a conceptual tool which he called "the macroscope" as it allows us to see the larger wholes—as a complement to the microscope that focuses on the smaller parts. He used this tool to examine the flows of matter, energy, and information that govern the global organism [⁶].

The biologist Gregory Stock [⁷] wrote a popular account of the process where individuals are increasingly tied to others through technology, forming a global superorganism which he calls *Metaman*. Like Spencer, he emphasizes the analogy between on-going social, economic and technical progress and biological development, comparing for example the growth of railway or communication networks with the growth of networks of arteries or nerves. A more systematic investigation of the correspondences between organisms and social systems can be found in the *Living Systems Theory* of James Grier Miller [⁸], which analyses the abstract functions, such as processing resources and information, protecting itself, learning, making decisions, ..., that any "living system", be it biological or social, must perform.

A different level of application of the organicist perspective is the *Gaia* hypothesis, according to which the planet Earth itself is a living organism [⁹]. This organism would be able to regulate its own essential variables, such as temperature and composition of the atmosphere. While popularized by James Lovelock in the 1970's, the underlying intuition is much older as well, as illustrated by the following quotation from the romantic author Edgar Allan Poe, where he observes that an intelligent global superorganism might not be aware of us, just as we are not aware of it:

I love to regard [the rocks, waters, forests... of the Earth] as the colossal members of one vast animate and sentient whole - a whole [...] whose life is eternity; whose thought is that of a

God; whose enjoyment is knowledge; whose destinies are lost in immensity; whose cognizance of ourselves is akin with our own cognizance of the *animalculae* which infest the brain - a being which we, in consequence, regard as purely inanimate and material, much in the same manner as these animalculae must regard us [Island of the Fay, 1850].

Compared to the global brain as we have defined it, this "Gaian" organism seems rather primitive. Moreover, as several authors have noted, humanity seems to act more like a parasite (Poe's "animalculae" are what we now would call bacteria) or 'tumor' of the encompassing Gaian organism, because of its unsustainable growth and exploitation of the Earth's resources [¹⁰, ¹¹]. The more optimistic outlook is that this parasite would evolve into a symbiote (cf. [¹²]) and from there into an organ that helps the superorganism to make informed decisions and solve complex problems. For example, Robert Muller, a former assistant Secretary-General of the United Nations and Chancellor of the U.N. University, proposes that we are all cells or perceptive nervous units of the Earth, and that the UN and its network of associated multinational organizations form part of its brain [¹³]. But to create an intelligent system on the global level, you first need to make sure that it has access to all relevant knowledge.

Encyclopedism: a universal knowledge network

The ideal of a publicly available record of all of humanity's knowledge is probably not much younger than the organicist metaphor, although it really comes to the fore only in the 18th century with the Enlightenment. An early summary can be found in the Oration (circa 1737) of the Chevalier de Ramsay, who describes one of the objectives of freemasonry as:

... to furnish the materials for a Universal Dictionary ... By this means the lights of all nations will be united in one single work, which will be a universal library of all that is beautiful, great, luminous, solid, and useful in all the sciences and in all noble arts. This work will augment in each century, according to the increase of knowledge.

The most influential implementers of this idea are the French Encyclopedists, led by Diderot and d'Alembert, whose *Encyclopedia* [¹⁴], published between 1751 and 1772, spread the ideas of rational inquiry, science, and technology, thus laying the foundations for the industrial and French revolutions.

Yet by the end of the 19th century, knowledge had grown so much that it no longer seemed possible to publish it in a single volume or collection. The Belgian Paul Otlet, the founding father of bibliography (or what is now called information science), therefore set out to tackle the practical problem of collecting and organizing the world's knowledge. He designed a structured system of documents containing texts or images connected by links [¹⁵], and founded the still active *Union of International*

Organizations [16] to help collect this knowledge. By 1935, Otlet had developed a conception of a global brain that seems eerily prescient of the world-wide web:

Man would no longer need documentation if he were assimilated into a being that has become omniscient, in the manner of God himself. To a less ultimate degree, a machinery would be created [that would register at a distance] everything in the universe, and everything of man, as it was produced. This would establish a moving image of the world, its memory, its true duplicate. From a distance, anyone would be able to read an excerpt, expanded and restricted to the desired subject, which would be projected onto an individual screen. In this way, anyone from his armchair will be able to contemplate creation, as a whole or in certain of its parts. ([17], pp. 390-391, my translation)

At about the same time, the British author H. G. Wells, who is best known for his science fiction novels, envisaged a *world brain* [18, 19] which he defined as "the idea of a permanent world encyclopaedia":

As the core of such an institution would be a world synthesis of bibliography and documentation with the indexed archives of the world. A great number of workers would be engaged perpetually in perfecting this index of human knowledge and keeping it up to date. ... There is no practical obstacle whatever now to the creation ... of a complete planetary memory ... accessible to every individual. ... [It] will supply the humanity of the days before us, with a common understanding and the conception of a common purpose and of a commonweal such as now we hardly dare dream of. And its creation is a way to world peace ... dissolving human conflict into unity [19].

Neither Otlet nor Wells had as yet a clear idea of the kind of technology needed to create such a knowledge system, although they speculated about future uses of filing systems, microfilm and telephone to store, retrieve and transmit information world-wide. The American Vannevar Bush [20], writing in 1945, is generally credited with inventing the idea of *hypermedia*—that is, chunks of information connected by associative links that can be called up automatically. Bush's vision adds little to the one of Otlet, though [15], and his conceived "memex" merely augments individual memory rather than integrating the knowledge of humankind. In the 1960's, Douglas Englebart, the computer pioneer who invented such ubiquitous interface elements like the mouse and windows, was also the first to implement a true hypertext. For him too, the primary motivation was to augment human intellect [21] in the face of the growing complexity of knowledge, although he focused beyond the individual to the organization, and what he later called "collective IQ".

In the 1970's, Theodore Nelson, who coined the words "hypertext" and "hypermedia", was probably the first to envisage a computer system for publishing and

linking documents on the global level [22]. His *Xanadu* system, however, never got further than a grand, inspiring vision, illustrated by a few rudimentary prototypes. The more pragmatic approach of the British scientist Tim Berners-Lee provided the foundation for the *World-Wide Web* in 1991 [23]. His primary innovation was to combine a simplified format for hypertext documents (HTML) with a universal scheme for locating documents on the Internet (URL). Thus, documents on different computers could be linked directly—depending on their subject matter rather than on their geographical location. The resulting web is truly *distributed* over the world, and therefore much more robust, open, and democratic than the centralized systems envisaged before [18]. The ease and freedom with which web documents can be created and linked, however, led to an anarchic proliferation of websites, many of which are poorly structured and with low quality information. This makes it difficult to find the information one is looking for. Therefore, Berners-Lee and others have started developing the next stage of the *semantic web* [23], in which knowledge would be organized according to consensual categorization schemes or "ontologies", thus in a way going back to Otlet's bibliographic indexing methods.

Emergentism: a higher level of consciousness

Although most authors have addressed the GB from a scientific or technological perspective, some have focused on its spiritual aspects. Similar to many mystical traditions, the GB idea points towards the achievement of a state of higher consciousness (the Buddhist's *Nirvana*), in which the individual loses its separate, subjective being and merges with humanity and perhaps even the world as a whole. Religious people might view this state of holistic consciousness as a union with God, the Tao, or what Emerson called the "Oversoul". Humanists might see it as the creation, by humanity itself, of an entity with God-like powers of cognition (cf. the preceding Otlet quote).

The best known author to develop this argument is the French paleontologist and jesuit priest Pierre Teilhard de Chardin, who combined his knowledge of evolution and theology into a mystical and poetic vision of future evolutionary integration [24]. According to Teilhard's *law of complexity-consciousness*, evolution is accompanied by increases in both complexity and consciousness, characterized by a growing number of connections between components. Thus, the human brain with its billions of neurons and synapses is the most complex and most conscious biological system. But evolution in the biosphere is followed by the emergence of the *noosphere*, the global network of thoughts, information and communication, and it is here that spiritual union will be achieved:

No one can deny that ... a world network of economic and psychic affiliations is being woven at ever increasing speed which envelops and constantly penetrates more deeply within each of us. With every day that passes it becomes a little more impossible for us to act or think otherwise than collectively. [²⁵]

We are faced with a harmonized collectivity of consciousness, the equivalent of a sort of super-consciousness. The idea is that of the earth becoming enclosed in a single thinking envelope, so as to form, functionally, no more than a single vast grain of thought on the cosmic scale... [24]

Not surprisingly, Teilhard's unorthodox views were suppressed by the Vatican. His major works were only published after his death in 1955, by the Belgian theologian Max Wildiers, who further developed Teilhard's ideas on the evolution of mind, focusing on the role of technology in the noosphere.

Inspired by Timothy Leary, the guru of the psychedelic age, and Herbert Kahn, the technology forecaster, the American futurist Jerome Glenn explored the connection between technological development and expansion of consciousness [²⁶]. He proposed that as we develop ever more sophisticated methods for sensing and processing information, the technology to support these processes and the enhanced human consciousness will gradually merge, forming a continuum which he called *Conscious-Technology*. This will produce a much higher level of intelligence and awareness, or what mystics call "enlightenment".

Peter Russell [²⁷], a British physicist interested in Eastern religions, proposed a simpler and more up-to-date conception of Teilhard's emergentist philosophy, and coined the expression "Global Brain" to describe it. After using Miller's living systems theory [8] to point out the similarities between global society and an organism, Russell focused on the mental development of this superorganism, emphasising consciousness-raising techniques like meditation that might help people worldwide to achieve a deeper synergy. Russell's "New Age" vision was brought into the Internet age by the German complexity theorist Gottfried Mayer-Kress [1]. Mayer-Kress notes that complex systems tend to undergo a phase transition to an emergent level of organization once their number of components reaches a certain large number (10 billion neurons in the brain, almost 10 billion people on earth), and once the communications between those components reach a certain degree of speed and intensity, as supported by the Internet and teleconferencing.

Although intuitively attractive, this emergentist perspective leaves a fundamental issue unanswered: precisely how and why will a new level of organization emerge? The numerical argument advanced by Russell and Mayer-Kress, while seemingly science-based, is in fact not more than a coarse analogy. E.g. at present the consensus seems to be that the human brain contains 100 rather than 10 billion neurons, invalidating any

argumentation that the world's population will soon reach a "brain-like" level. To understand global integration, we need a more in-depth, qualitative understanding of the evolution of emergent levels.

Evolutionary cybernetics: towards an integrated theory

While most conceptions of the GB are based on some kind of progressive evolution towards higher levels of complexity and integration, this assumption receives surprisingly little support from the theory of evolution itself. The traditional (neo-)Darwinist theory emphasizes the gradual, erratic, and non-directed character of variation and natural selection, and the struggle for existence between selfish organisms or genes. It is only in the last decade that biologists have started to focus on the "major transitions" in evolution, such as the emergence of multicellular organisms out of single cells, or societies out of individuals—studying the specific circumstances in which components can turn from selfish, competing individuals to cooperating members of a collective [28].

The general consensus seems to be that, while such transitions have happened, they are rare and difficult to achieve, because they require sophisticated control mechanisms to protect the cooperative from being exploited by "free riders", i.e. components that profit from the efforts of others without investing anything in return [29]. Humans in particular are intrinsically ambivalent, vacillating between altruism and solidarity on the one hand, and selfishness and competition on the other. The conclusion is that humanity cannot as yet be viewed as a superorganism, and that there remain fundamental obstacles on the road to an eventual global integration. Evolutionary biology thus tends to side with the conflict model of present-day sociology, questioning the organicist and emergentist perspectives. Yet, it ignores the role of shared knowledge and communication technologies emphasized by the encyclopedist perspective, which—at least in Wells's utopian view—would seem to allow overcoming conflicts.

Cybernetics is the discipline that studies levels of organization in complex systems, with the emphasis on communication, control and knowledge [30]. Traditionally, though, it was limited to modelling existing forms of organization, whether biological, social or technical, neglecting the issue of how this organization had arisen. The new approach of *evolutionary cybernetics* [5] integrates the Darwinian logic of variation and selection with the cybernetic analysis of emergent levels. It is thus eminently suited to model the evolution of a GB-like system.

This approach was originated by the Russian-American computer scientist Valentin Turchin, in his 1977 book entitled "The Phenomenon of Science" [31] (as a tribute to Teilhard's "The Phenomenon of Man"). Turchin's most important contribution is the concept of *metasystem transition*: the evolution of a higher level of control and cognition. In analogy with the emergence of multicellular organisms, Turchin predicted

that humans will be integrated into a global *superbeing*, communicating through the direct connection of their nervous systems. The aforementioned systems scientist de Rosnay independently arrived at a similar conception of an evolutionary process that recursively generates higher levels of complexity, producing a *planetary brain* for the *cybiont*, or global cybernetic organism [12]. Joined by the systems scientist Cliff Joslyn in 1989 and by myself in 1990, Turchin founded the Principia Cybernetica Project [32], an international organization that uses the Internet to collaboratively develop an evolutionary-cybernetic knowledge network. This added the encyclopedist perspective to Turchin's synthesis of emergentist and organicist approaches.

Neither Turchin nor de Rosnay had tackled the problem of free riders, though. In collaboration with the evolutionary social scientist Donald T. Campbell [29], I proposed a possible solution, arguing that shared knowledge or culture ("memes") can function like a control mechanism to thwart free riders, and that its spread will be facilitated by global communication technology. A more general version of this process was proposed a few years later by the Australian social scientist John Stewart [33]. He argues that any system, whether an individual, institution or ideology, that manages to take control of a collective—even if for initially selfish purposes—will eventually evolve into an efficient "manager" that keeps selfish abuses in check, because it is in its own interest to have the collective function synergetically. As a result, evolution produces ever wider and deeper synergy, up to the global level. A similar conclusion was reached by the American author Robert Wright [34], who examined the historical role of different technologies and institutions, such as writing, money and law, in turning the "zero-sum" competition between individuals into a "positive-sum" cooperation.

None of these evolutionary mechanisms as yet provides a concrete model for the role of the Internet. It is here that the cybernetic perspective is most useful. Turchin's sequence of metasystem transitions not only describes the social integration of individuals, but the stepwise complexification of the nervous system. In 1996 I argued that the Internet is undergoing similar transitions to a higher level of intelligence [35]. At the same time, in collaboration with my PhD student Johan Bollen I designed concrete algorithms that would allow the web to become a learning and "thinking" system. The core idea is that frequently used sequences of hyperlinks are reinforced and eventually collapsed into a single link, similar to the "Hebbian" strengthening of synapses in the brain. The result is that the web learns from its users what they—collectively and individually—need, anticipating their questions, and thus minimizing their effort in finding answers [36]. As such, the web would turn into an intelligent, adaptive, self-organizing system of shared knowledge, structured in a much more flexible and intuitive way than the formal classification schemes conceived by Berners-Lee and others.

Unlike material resources, knowledge and information do not diminish by being shared with others (economists call this property "non-rivalry"). Since the learning web

would make this sharing effortless and free, this enables a positive-sum interaction in which everyone gains by making their individual knowledge and experience available to others. This provides a continuing incentive for further cognitive integration. The web plays here the role of a shared memory, that collects, organizes and makes available the collective wisdom [37]. It achieves this without demanding anything from its users or contributors beyond what they would have had to invest if they were working on their own—thus removing any incentive for free-riding. This is the perspective of *collective intelligence* [38], according to which living or computational agents can solve much more complex problems when working together than in separation. Collective intelligence is enhanced by a division of labor, where the cognitive processing is *distributed* over a variety of specialized components, each with their individual experience—whether human or technological [39].

In 1996, I came in contact with the American mathematician Ben Goertzel, who had also been developing algorithms for an intelligent computer system at the global level [40]. Together, we founded the *Global Brain Group* to discuss the issues, being joined by most of the active researchers in the domain, including Turchin, de Rosnay, Stock, Russell and Mayer-Kress. The special issue of which this paper is part grew out of the first workshop organized by this group in 2001.

Conclusion

It is intuitively attractive to see humanity together with its shared knowledge stores and communication channels as an intelligent, organism-like system. Many thinkers have therefore developed a conception of such a "global brain". This way of thinking has further gained in popularity with globalization and the explosive growth of the Internet. Yet, if we wish to use this perspective to understand the future development of society and technology, we need to go beyond metaphor, and propose concrete mechanisms and models [35]. This paper has reviewed the main conceptual strands available to build such an integrated theory.

Historically, I distinguished three approaches: *organicist*, *encyclopedist* and *emergentist*. While each of these conceptions provides an inspiring metaphor for understanding and guiding social development, each also has major shortcomings. The organicist perspective, by ignoring conflicts and competition and by studying the way things are rather than how they might be or ought to be, tends to promote a status quo. The encyclopedist view, while inherently progressive, relies too much on rational planning and organization, ignoring not only the potential for conflict, but the intrinsic difficulty of unifying and centralizing something as context-dependent, complex and changeful as the world's knowledge. The emergentist perspective, while emphasizing the potential for self-organization and radical evolutionary innovation, seems to suffer

from wishful thinking, assuming that we just need to more communicate, become conscious, or use technology to see a global brain emerge.

I have argued that these shortcomings can be overcome by integrating two existing theoretical frameworks: evolution and cybernetics. Biological evolution points us to the intrinsic sources of conflict, and how these have been overcome by evolving synergetic systems and control mechanisms against free riders. Cybernetics shows us how systems and control are organized in levels, and based on knowledge and communication. Evolutionary cybernetics introduces the concept of metasystem transition: the self-organization of individual components into a positive-sum system that functions at a higher level of intelligence and consciousness. The specific models associated with cybernetics, such as neural networks or distributed knowledge systems, help us to design concrete technologies that could support such a collective intelligence. The world-wide web, finally, provides an extremely flexible and powerful platform for testing and implementing such technologies at the global level.

References

- [1] Mayer-Kress, G. & Barczys C.: The Global Brain as an Emergent Structure from the Worldwide Computing Network, and its Implications for Modelling, *The Information Society 11:1*, 1-28 (1995).
- [2] Stock, G.: *Metaman: the merging of humans and machines into a global superorganism*. Simon & Schuster, New York (1993).
- [3] Spencer, Herbert: Principles of sociology, (ed. by Stanislaw Andreski) (MacMillan, London 1969).
- [4] Bukharin N.I. : Historical Materialism - a System of Sociology, International Publishers, 1925
- [5] Heylighen F.: The Global Superorganism: an evolutionary-cybernetic model of the emerging network society, *Journal of Social and Evolutionary Systems* (2002)
- [6] de Rosnay, J. *The Macroscope*. Harper & Row, New York (1979).
- [7] Stock, G.: *Metaman: the merging of humans and machines into a global superorganism*. Simon & Schuster, New York (1993).
- [8] Miller, J. G. *Living Systems*. McGraw Hill, New York (1978).
- [9] Lovelock, E. *The Ages of Gaia: A Biography of Our Living Earth* , W.W. Norton & Company; Revised and Updated edition (1995)
- [10] Hern, Warren M. . Has the Human Species Become a Cancer on the Planet? A Theoretical View of Population Growth as a Sign of Pathology. *Current World Leaders* 36(6): 1089-1124. (1993)
- [11] Russell, P.: *The Global Brain Awakens*, Miles River Press (1995).
- [12] de Rosnay, J.: *The Symbiotic Man*. McGraw-Hill. (2000)

[¹³] Muller, Robert, *The Birth of a Global Civilization*. Anacortes, Washington: World Happiness and Cooperation (1991).

[¹⁴] Diderot, D., & d'Alembert, J. (Eds.). *Encyclopédie ou dictionnaire raisonné des sciences, des arts et des métiers* [Encyclopedia or systematic dictionary of the sciences, arts and crafts]. Paris: Briasson, David, Le Breton, Durand. Gendzier (1751-1772),

[¹⁵] Boyd Rayward, W.: "Visions of Xanadu: Paul Otlet (1868-1944) and Hypertext," *Journal of the American Society of Information Science* 45 :235-250, (1994)

[¹⁶] Judge, Anthony: *Union of International Associations – Virtual Organization*. Paul Otlet's 100-year Hypertext Conundrum? (2001)

<http://www.laetusinpraesens.org/docs/otlethyp.php>.

[¹⁷] Otlet, Paul : *Monde: essai d'universalisme*, Brussels, Editions du Mundaneum, (1935)

[¹⁸] Boyd Rayward, W.: "H.G. Wells's Idea of a World Brain: a Critical Re-Assessment," *Journal of the American Society of Information Science* 50 :557-573, (1999)

[¹⁹] Wells, H.G.: *World Brain*. London: Methuen (1938).

[²⁰] Bush, V. (1945) "As we may Think" in Nyce, J.M. and Khan, P. *From Memex to Hypertext: Vannevar Bush and the Mind's Machine* (Boston: Academic Press), pp. 85-107 (1991).

[²¹] Englebart, Douglas C. "A Conceptual Framework for the Augmentation of Man's Intellect." In Howerton, Paul (ed.) *Vistas in Information Handling vol 1, The Augmentation of Man's Intellect by Machine* (pp. 11-29). Washington, D.C.: Spartan Books (1963)

[²²] Nelson, Ted: *Literary Machines*. Swarthmore, Pa.: the Author, (1983)

[²³] Berners-Lee, Tim: *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web*, HarperBusiness (2000)

[²⁴] Teilhard de Chardin, P.: *Le Phénomène Humain*. Seuil, Paris (1955). (translated as: *The Phenomenon of Man* . Harper & Row, New York (1959)).

[²⁵] Teilhard de Chardin, Pierre : *The Formation of the Noosphere: a Plausible Biological Interpretation of Human History*, in: *The Future of Man*, New York, Harper and Row, 1969; first published in: *Revue des Questions Scientifiques*, (Louvain), January, 1947, pp. 7-35.

[²⁶] Glenn, Jerome Clayton: *Future Mind* (Acropolis, Washington DC) (1989).

[²⁷] Russell, P.: *The Global Brain Awakens.*, Miles River Press (1995).

[²⁸] Maynard Smith, J. & Szathmáry E. (1995) *The Major Transitions in Evolution*. W.H. Freeman, Oxford.

- [²⁹] Heylighen F. & Campbell D.T. : “Selection of Organization at the Social Level: obstacles and facilitators of metasystem transitions”, *World Futures: the Journal of General Evolution* 45, p. 181-212(1995).
- [³⁰] Heylighen F. & Joslyn C.: "Cybernetics and Second Order Cybernetics", in: R.A. Meyers (ed.), *Encyclopedia of Physical Science & Technology* (3rd ed.), Vol. 4 , (Academic Press, New York), p. 155-170 (2001).
- [³¹] Turchin, Valentin: *The Phenomenon of Science. A Cybernetic Approach to Human Evolution*, Columbia University Press, New York (1977).
- [³²] Heylighen F. : "Foundations and Methodology for an Evolutionary World View: a review of the Principia Cybernetica Project", *Foundations of Science*, 5, p. 457-490.(2000)
- [³³] Stewart, J. E.: *Evolution's Arrow: The direction of evolution and the future of humanity* (Chapman Press, Australia): <<http://www4.tpg.com.au/users/jes999/>> (2000)
- [³⁴] Wright, R.: *Non-Zero. The Logic of Human Destiny* (Pantheon Books) (2000).
- [³⁵] Heylighen F. & Bollen J.: The World-Wide Web as a Super-Brain: from metaphor to model, in: *Cybernetics and Systems '96* R. Trappl (ed.), (Austrian Society for Cybernetics), p. 917-922. (1996)
- [³⁶] Heylighen F. & Bollen J.: “Hebbian Algorithms for a Digital Library Recommendation System”, in *Proceedings 2002 International Conference on Parallel Processing Workshops* IEEE Computer Society Press (2002)
- [³⁷] Heylighen F.: Collective Intelligence and its Implementation on the Web: algorithms to develop a collective mental map, *Computational and Mathematical Theory of Organizations* 5(3), 253-280 (1999).
- [³⁸] Lévy P. , *Collective Intelligence: Mankind's Emerging World in Cyberspace* Plenum, New York, (1997)
- [³⁹] Hollan J., Hutchins E. & Kirsh D.: Distributed Cognition: toward a new foundation for human-computer interaction research, *ACM Transactions on Human-Computer Interaction* 7(2), p.174-196 (2000).
- [⁴⁰] Goertzel, B.: *Creating Internet Intelligence: Wild Computing, Distributed Digital Consciousness, and the Emerging Global Brain* (Plenum) (2001)