The Global Superorganism: An Evolutionary-cybernetic Model of the Emerging Network Society

Francis Heylighen
CLEA, Vrije Universiteit Brussel

ABSTRACT

The organicist view of society is updated by incorporating concepts from cybernetics, evolutionary theory, and complex adaptive systems. Global society can be seen as an autopoietic network of self-producing components, and therefore as a living system or 'superorganism'. Miller's living systems theory suggests a list of functional components for society's metabolism and nervous system. Powers' perceptual control theory suggests a model for a distributed control system implemented through the market mechanism. An analysis of the evolution of complex, networked systems points to the general trends of increasing efficiency, differentiation and integration. In society these trends are realized as increasing productivity, decreasing friction, increasing division of labor and outsourcing, and increasing cooperativity, transnational mergers and global institutions. This is accompanied by increasing functional autonomy of individuals and organisations and the decline of hierarchies. The increasing complexity of interactions and instability of certain processes caused by reduced friction necessitate a strengthening of society's capacity for information processing and control, i.e. its nervous system. This is realized by the creation of an intelligent global computer network, capable of sensing, interpreting, learning, thinking, deciding and initiating actions: the 'global brain'. Individuals are being integrated ever more tightly into this collective intelligence. Although this image may raise worries about a totalitarian system that restricts individual initia-

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tive, the superorganism model points in the opposite direction, towards increasing freedom and diversity. The model further suggests some specific futurological predictions for the coming decades, such as the emergence of an automated distribution network, a computer immune system, and a global consensus about values and standards.

KEYWORDS: superorganism, global brain, collective intelligence, cybernetics, networks, evolution, self-organisation, society, globalization, complexity, division of labor, living systems.

INTRODUCTION

It is an old idea that society is in a number of respects similar to an organism, a living system with its cells, metabolic circuits and systems. In this metaphor, different organisations or institutions play the role of organs, each fulfilling its particular function in keeping the system alive. For example, the army functions like an immune system, protecting the organism from invaders, while the government functions like the brain, steering the whole and making decisions. This metaphor can be traced back at least as far as Aristotle (Stock 1993). It was a major inspiration for the founding fathers of sociology, such as Comte, Durkheim and especially Spencer (1969).

The organicist view of society has much less appeal to contemporary theorists. Their models of society are much more interactive, open-ended, and indeterministic than those of earlier sociologists, and they have learned to recognize the intrinsic complexity and unpredictability of society. The static, centralized, hierarchical structure with its rigid division of labor that seems to underlie the older organicist models appears poorly suited for understanding the intricacies of our fast-evolving society. Moreover, a vision of society where individuals are merely little cells subordinated to a collective system has unpleasant connotations to the totalitarian states created by Hitler and Stalin, or to the distopias depicted by Orwell and Huxley. As a result, the organicist model is at present generally discredited in sociology.

In the meantime, however, new scientific developments have done away with rigid, mechanistic views of organisms. When studying living systems, biologists no longer focus on the static structures of their anatomy, but on the multitude of interacting processes that allow the organism to adapt to an ever changing environment. Most recently, the variety of ideas and methods that is commonly grouped under the header of 'the sciences of complexity' has led to the understanding that organisms are self-organizing, adaptive systems. Most processes in such systems are decentralized, indeterministic and in constant flux. They thrive on 'noise', chaos, and creativity. Their collective intelligence emerges out of the free interactions between individually autonomous components. Models that explain organisation and adaptation through a central, 'Big Brother'-like planning module have been found unrealistic for most systems.

This development again opens up the possibility of modelling both organisms and societies as complex, adaptive systems (CAS). Indeed, the typical examples studied by the CAS approach (Holland 1992, 1996) are either biological (the immune system, the nervous system, the origin of life) or social (stock markets, economies [Anderson, Arrow, and Pines 1988], ancient civilisations). However, this approach is as yet not very well developed, and it proposes a set of useful concepts and methods rather than an integrated theory of either organisms or societies.

The gap may be filled by a slightly older tradition, which is related to the CAS approach: *cybernetics and systems theory*. Although some of the original cybernetic models may be reminiscent of the centralized, hierarchical view, more recent approaches emphasize self-organisation, autonomy, decentralization and the interaction between multiple agents. Within the larger cybernetics and systems tradition, several models were developed that can be applied to both organisms and social systems: Miller's (1978) living systems theory, Maturana's and Varela's (1980, 1992) theory of autopoiesis, Powers' (1973, 1989) perceptual control theory, and Turchin's (1977) theory of metasystem transitions.

These scientific approaches, together with the more mystical vision of Teilhard de Chardin (1955), have inspired a number of authors in recent years to revive the organicist view (de Rosnay 1979, 1986, 2000; Stock 1993; Russell 1995; Turchin 1977, 1981; Chen and Gaines 1997). This gain in interest was triggered in particular by the spectacular development of communication networks, which seem to function like a nervous system for the social organism. However, these descriptions remain mostly on the level of metaphor, pointing out analogies without analyzing the precise mechanisms that underlie society's organism-like functions.

The present paper sets out to develop a new, more detailed, scientific model of global society which integrates and builds upon these various approaches, thus updating the organicist metaphor. The main contribution I want to make is a focus on the process of evolution, which constantly creates and develops organisation. Because of this focus on on-going development, the proposed model should give us a much better understanding of our present, fast changing society, and the direction in which it is heading. The 'cybernetic' foundation in particular will help us to analyze the increasingly important role of information in this networked society.

The main idea of this model is that global society can be understood as a superorganism, and that it becomes more like a superorganism as technology and globalization advance. A superorganism is a higher-order, 'living' system, whose components (in this case, individual humans) are organisms themselves. Biologists agree that social insect colonies, such as ant nests or bee hives, can best be seen as such superorganisms (Seeley 1989). If individual cells are considered as organisms, then a multicellular organism too is a superorganism. Human society, on the other hand, is probably more similar to 'colonial' organisms, like sponges or slime molds, whose cells can survive individually as well as collectively. Unlike social insects, humans are genetically ambivalent towards social systems, as illustrated by the remaining conflicts and competition between selfish individuals and groups within the larger society (Heylighen and Campbell 1995; Campbell 1982, 1983).

The issue here, however, is not so much whether human society *is* a superorganism in the strict sense, but in how far it is useful to model society *as if it were* an organism. This is what Gaines (1994) has called the 'collective stance': viewing a collective as if it were an individual in its own right. My point is that this stance will help us to make sense of a variety of momentous changes that are taking place in the fabric of society, and this more so than the more traditional stance which views society merely as a complicated collection of interacting individuals (cf. Heylighen and Campbell 1995). More generally, my point is that both societies and biological organisms can be seen as special cases of a more general category of 'living' or 'autopoietic' systems that will be defined further on.

The paper will first try to determine what it exactly means for a system to be an ‘organism’, and look in more detail at two essential subsystems of any organism: metabolism and nervous system. It will then argue that society's metabolism and nervous system, under the influence of accelerating technological change, are becoming ever more efficient and cohesive. This evolution will in particular give rise to the emergence of a ‘global brain’ for the superorganism. Finally, the paper will try to look at some of the radical implications of this development for the future.

SOCIETY AS AN AUTOPOIETIC SYSTEM

If we want to characterize society as a living system, we will first need to define what life is, in a manner sufficiently general to be applicable to non-DNA-based systems. Perhaps the best abstract characterization of living organisation was given by Maturana and Varela (1980, 1992): *autopoiesis* (Greek for ‘self-production’). An autopoietic system consists of a network of processes that recursively produces its own components, and thus separates itself from its environment. This defines an autopoietic system as an autonomous unit: it is responsible for its own maintenance and growth, and will consider the environment merely as a potential cause of perturbations for its inner functioning. Indeed, a living cell can be characterized as a complex network of chemical processes that constantly produce and recycle the molecules needed for a proper functioning of the cell.

Reproduction, which is often seen as the defining feature of life, in this view is merely a potential application or aspect of autopoiesis: if you can produce your own components, then you can generally also produce an extra copy of those components. Reproduction *without* autopoiesis – which can be designated more precisely as *replication* – does not imply life: certain crystals, molecules and computer viruses can replicate without being alive. Conversely, autopoiesis without reproduction *does* imply life: you would not deny your childless aunt the property of being alive because she is no longer capable of giving birth.

Taking autopoiesis rather than reproduction as a defining characteristic removes one major obstacle to the interpretation of societies as living: although societies generally do not reproduce, they undoubtedly produce their own components. The physical components of society can be defined as all its human members together with their artefacts (buildings, cars, roads, computers, books, etc.). Each of these components is produced by a combination of other components in the system. People, with the help of artefacts, produce other people, and artefacts, with the help of people, produce other artefacts. Together, they constantly recreate the fabric of society. (To the non-human components of society we may in fact add all domesticated plants and animals, that is to say, that part of the global ecosystem whose reproduction is under human control. As human control expands, this may come to include the complete biosphere of the Earth, so that the social superorganism may eventually encompass Gaia, the 'living Earth' superorganism postulated by some theorists.)

These processes of self-production clearly exhibit the network-like, cyclical organisation that characterizes autopoiesis (see Fig. 1): a component of type *a* is used to produce a *b* component, which is used to produce a *c*, and so, on, until a *z* is again used to produce an *a*.

Although societies rarely reproduce, in the sense of engendering another, independent society, their autopoiesis gives them in principle the capacity for reproduction. It could be argued that when Britain created colonies in regions like North America and Australia, these colonies, once they became independent, should be seen as offspring of British society. Like all children, the colonies inherited many characteristics, such as language, customs and technologies, from their parent, but still developed their own personality. This form of reproduction is most similar to the type of vegetative reproduction used by many plants, such as vines and grasses, where a parent plant produces offshoots, spreading ever further from the core. When such a shoot, once it has produced its own roots, gets separated from the mother plant, it will survive independently and define a new plant. Thus, the growth of society is more like that of plants than like that of the higher animals that we are most familiar with: there is no *a priori*, clear separation between parent and offspring. As we will discuss further, in the present globalized world geographical separation is no longer sufficient to create independence. Yet, we could still imagine global society spawning offspring in the form of colonies on other planets.

A society, like all autopoietic systems, is an open system: it needs an input of matter and energy (resources) to build its components, and it will produce an output of matter and energy in the form of waste products and heat. In spite of being thermodynamically open, an autopoietic system is *organisationally closed*: its organisation is determined purely internally. The environment does not tell the system how it should organize itself; it merely provides raw material. The autopoietic system contains its own knowledge on how to organize its network of production processes. *Closure* means that every component of the system is produced by one or more other components of the same system. No component or subsystem of components is produced autonomously. If it were, the subsystem would itself constitute an independent autopoietic system, instead of being merely a component of the overall system.

This requirement of closure is perhaps what makes the application of autopoiesis to social systems so controversial. Closure distinguishes what is inside, part of the system, from what is outside, part of the environment. Maturana and Varela's (1980) original definition of autopoiesis adds to this that an autopoietic system should produce its own *boundary*, that is, a spatial or topological separation between system and environment. Unlike biological organisms, most social systems do not have a clear spatial boundary. Moreover, for most social systems the closure requirement is only partially fulfilled. For example, a country may produce most of its essential components internally, but it will still import some organized components (people, artefacts) or knowledge from outside. This means that any boundary we could draw around a social system will be porous or fuzzy. The only way to fulfill the requirement of organisational closure is to consider *global society as a whole* as an autopoietic system. None of its subsystems, whether they be countries, corporations, institutions, communities or families is properly autopoietic. All of them are to some extent dependent on outside organisation for their maintenance.

This observation may explain why different authors disagree about whether social systems can be autopoietic. Although Maturana and Varela, the originators of the autopoiesis concept, would restrict it to biological organisms, several others (*e.g.* Luhmann 1995; Robb 1989; Zeleny and Hufford 1991; see Mingers 1994, for a review) have suggested that social systems can be autopoietic, while disagreeing about exactly which systems exhibit autopoiesis. To me, it seems that the controversy can be resolved by only considering global society, the supersystem which encompasses all other social systems, as intrinsically autopoietic.

The problem of the boundary can be resolved by relaxing the requirement that an autopoietic system should produce a physical boundary in space (like the membrane enveloping cells). Although countries, cities or firms sometimes do produce physical boundaries, such as walls or an 'Iron Curtain', planetary society has no need for such a boundary. Indeed, the Earth on which we live offers its own boundary, consisting of the atmosphere which protects the social organism from cosmic rays and meteorite impact, and the lithosphere, which protects its from the heat and magma inside the planet. If an organism, such as a hermit crab, uses a readily available encasing or shell for its protection, rather than invest effort in producing one of its own, then we can hardly blame it for not being sufficiently autopoietic.

If we take the concept of the boundary in a less literal, not purely physical sense, then society clearly does separate its internal components from the environment. The mechanism an organism uses to distinguish and separate insiders from outsiders is the immune system. The immune system is programmed to recognize and expel all alien material, all 'trespassers' that do not obey the rules of the game. These trespassers may in fact include internally produced components, such as cancer cells, that for some reason have stopped obeying the laws that govern the organisation. Society too has an immune system that will try to control both external invaders (*e.g.* wild animals, infectious diseases, hurricanes, foreign enemies) and internal renegades (*e.g.* criminals, terrorists, computer viruses). Basic components of a society's immune system are the police, justice and army.

Both the greatest strength and the greatest weakness of the concept of autopoiesis is its all-or-none character: a system is either organizationally closed, or it is not; it is either alive, or dead. In practice, the distinction between internally and externally produced organisation is not always that clear-cut. Organisms do not just need raw matter and energy as input: these resources must exhibit some form of organisation. For example, an animal, unlike a plant, cannot produce its components on the basis of air, water and minerals. The resources an animal needs must already have gone through some degree of organisation into complex organic molecules, such as lipids, carbohydrates, proteins and vitamins. Similarly, society is to some degree dependent on organisation in the outside world. For example, our present society is dependent for furniture and firewood on trees, and is dependent for energy on fossil fuels produced by plants millions of years ago.

This observation suggests that we distinguish *degrees* of autopoiesis: a system will be more autopoietic if it produces more of its organisation internally, and thereby becomes less dependent on its environment. As we will discuss later, the evolution of society will typically lead to more autonomy and a greater capacity to internally produce organisation with a minimum of external input.

To understand how society achieves autopoiesis, we must look in more detail at how the network of production processes can produce a stable organisation, in spite of a variable input of resources and various perturbations in the environment. This mechanism can be functionally decomposed into different tasks to be performed by different subsystems. The most important decomposition is the one distinguishing metabolism, responsible for the processing of matter and energy, and nervous system, responsible for the processing of information. The purpose of both subsystems is to maintain a stable identity by compensating or buffering the effect of perturbations. We will now discuss in more detail the different components for each of the subsystems, and the way they are connected.

METABOLISM: PROCESSING OF MATTER-ENERGY

Organisms are *dissipative systems* (Nicolis and Prigogine 1977): because of the second law of thermodynamics, they must export entropy or heat in order to maintain a dynamic steady state. This means that matter and/or energy must enter the system in low entropy form (input I in Fig. 1) and leave the system in high entropy form (output O in Fig. 1), after undergoing a number of conversions. The entropy that is dissipated or 'wasted' by the system is needed to keep up the cycle of production processes that maintains its organisation.

Although autopoiesis theorists focus on the closed, internal cycle of processes inside an organism, the fact that this cycle has an input and an output allows us to make a more of less 'linear' decomposition, which follows matter sequentially from the moment it enters the system, through the processing it undergoes, until the moment it exits. The systems theorist James Grier Miller (1978) has proposed a detailed decomposition scheme which can be used to analyze any 'living system', from a cell to a society. It must be emphasized that such decomposition is *functional*, but not in gen eral *structural*. This means that the functional subsystems we will distinguish do not necessarily correspond to separate physical components: the same function can be performed by several physical or structural components, while the same component can participate in several functions. Although complex organisms tend to evolve *organs*, *i.e.* localized, structural components specialized in one or a few functions (*e.g.,* the heart for pumping blood), other functions remain distributed throughout the organism (*e.g.*, the immune system).

Since this decomposition does not take into account autopoiesis or organizational closure, Miller applies his living system model also to systems – such as organs or communities – which are organizationally open and which I therefore would not classify as 'organisms'. It seems to me that to fully model organism-like systems, we need to integrate organizational closure with its focus on cycles and thermodynamical openness with its focus on input-output processing (cf. Heylighen 1990). In the following I will discuss the main functional subsystems of an 'organism', using examples both from the animal body and from society. For the societal examples I will focus on artefacts, so as not to repeat the bodily functions that society's human components share with other biological organism.

Table 1

Functional subsystems of the metabolism (processing of matter-energy) in animals and in societies

Function	**Body**	**Society**
Ingestor	eating, drinking, inhaling	mining, harvesting, pumping
Converter	digestive system, lungs	refineries, processing plants
Distributor	circulatory system	transport networks
Producer	stem cells	factories, builders
Extruder	urine excretion, defecation, exhaling	sewers, waste disposal, smokestacks
Storage	fat, bones	warehouses, containers
Support	skeleton	buildings, bridges
Motor	muscles	engines, people, animals

The first function in Miller's model is the *ingestor*, the subsystem responsible for bringing matter and energy from the environment into the system. In Fig. 1, for example, the components *a* and *b*, that directly receive input from the environment, participate in the ingestor function. In animals, this role is typically played by mouth and nose, to swallow food and inhale air. In society, the ingestor is not so clearly localized. Its role is played by diverse systems such as mines and quarries, which extract ores from the soil, water pits, and oil pumping installations. The next processing stage takes place in the *converter*, which transforms the raw input into resources usable by the system. For example, in Fig. 1 insofar that *a* and *b* have not already processed the input they received from the environment, we could situate the converter function in components such as *g* that receive their input from *a* or *b*. In the body, this function is carried out by the digestive system, which reduces diverse morsels of food to simple sugars, fatty acids and amino acids, and by the lungs which ensure that the oxygen fraction of the inhaled air is dissolved into the blood, where it is taken up by the hemoglobin in the red blood cells. In society, the converter function is performed by different refineries and processing plants, which purify water, oil and ores.

A usually subsequent processing stage is transport to those places where the resources are needed. This is the responsibility of the *distributor*. In an autopoietic network such as Fig. 1 all components whose output is similar to their input, but delivered at a different location, can be said to partake in the distribution function. In animals, the distributor function is carried out by the circulatory system: heart and blood vessels. In society, this is the role of the transport system: pipelines, ships, railways, planes, roads. Resources that have arrived at their destination are then processed in order to produce components for the organism. In animals, this *producer* function is carried out by stem cells and glands that produce either other cells or specific chemicals, such as enzymes and hormones. In society, this is done by different plants and factories, producing specialized goods. These products can again be transported by the distributor to wherever they are needed.

One destination where many products end up is *storage*: since the supply of resources from the environment is variable, and internal production cannot always be adjusted to the present need, it is necessary to have a reserve of resources and products that will help to buffer against fluctuations. In an autopoietic network, components whose output is similar to their input, but delivered at a later time, can be seen as contributing to the storage function. In the body, different organs can fulfill the function of storage for different products. The most general reserve is the one of fat, which can be used as an all-round supply of energy. In society, products are stored in warehouses, silos and containers. Another important destination for products is the *support* function, which physically upholds, protects and separates different parts of the organism. In the body, this function is performed by the skeleton. In society as a whole, which does not have a clear physical structure, the support function is not really needed, but locally it is performed by structures such as buildings, bridges and walls. Another destination is the *motor*, the subsystem that uses energy to generate motion for the organism. In the body, the motor function is performed by muscles, in society by different engines and machines.

Products are typically transformed and recycled into other products. For example, when a cell dies, the lipids that form its membranes will be reused by the body to build other membranes, or stored in fat reserves. In society, the steel of discarded cars will be reprocessed to build cans, steel rods or new cars. Because of the second law of thermodynamics, processes can never be completely reversed: there is always some loss, which is accompanied by the production of entropy. This means that processes will always bring about waste, which cannot be fully recycled. These waste products must be separated from the still usable products and collected. In the body, this is the function of the liver and kidneys, which filter waste products out of the blood. In society, it is carried out by garbage collectors and installations for the treatment of waste. The final matter processing subsystem is the *extruder*, which expulses the waste products out of the system. In the network of Fig. 1, the components *d* and *e* that deliver output straight into the environment, can be seen as part of the extruder. In the body, this function is performed by the urinary tract, the rectum, and the lungs, which get rid respectively of the liquid, solid and gaseous wastes. In society, the respective subsystems are sewers, garbage dumps, and chimneys or exhausts.

NERVOUS SYSTEM: INFORMATION AND CONTROL

Before proceeding with Miller's functional decomposition of information processing, we must discuss the overall function of information in a closed organisation. As Maturana and Varela (1980, 1992) like to emphasize, an autopoietic system is not *informed* by the environment: its form is determined purely by its internal organisation. Autopoietic systems are self-organizing. Data from the environment are only needed to warn the system about perturbations of normal functioning, that may damage or destroy its organisation. By appropriately counteracting or compensating for these perturbations, the system can maintain an invariant organisation in a variable environment (homeostasis).

Thus, organisms are by definition control systems in the cybernetic sense (Ashby 1964): they *regulate* or *control* the values of certain essential variables, so as to minimize deviations from the optimum range. For example, to sustain their intricate organisation, warm-blooded animals must maintain their body temperature within a close range of temperatures (for humans, roughly around 36.5 degrees Celsius). If the temperature of the environment changes, internal processes, such as transpiration or shivering, will be activated to counteract the effect of these perturbations on the internal temperature.

Possibly the clearest overall model of such regulation is proposed by William Powers' (1973, 1989) theory of living control systems. In this model, the behavior or sequence of actions of an organism is explained solely as an on-going attempt to bring the situation perceived by the organism as close as possible to its goal or preferred state ('reference level'). Actions change the state of the environment, and this state is perceived by the organism in order to check in what way it deviates from the goal. The sensed deviation triggers another action, intended to correct the remaining deviation. The effect of this action is again sensed, possibly triggering a further action, and so on, in a continuing negative feedback loop (see Fig. 2). This loop, if it functions well, keeps the system in a remarkably stable state, in spite of the continuous tug of war between environmental perturbations and compensating actions.

Although the resulting state may look largely static, the power exerted to counteract perturbations requires a constant supply of energy. As Powers shows with his mathematical models, an effective control loop is characterized by *amplification*: small deviations must be compensated by relatively large actions. Otherwise, the result will be merely a give and take between organism and environment, and the result will depend as much on the perturbation as on the action. With large amplification, on the other hand, the result will be much closer to the system's goal than to the external disturbances. In addition to energetic action, such amplification requires very fine-grained, sensitive perception, so that deviations can be detected at the earliest stage where relatively little energy may be sufficient to counteract them.

The different goals or reference levels for the different variables that an organism tries to optimize are typically arranged in a hierarchy, where a combination of perception and a higher level goal determines a goal at the lower level. Thus, goals are not static but adapt constantly to the perceived situation. This perception is not an objective reflection of the state of the environment: it is merely a registration of those aspects of the environment that are relevant to the system's goals, which themselves are subordinated to the overall goal of survival and reproduction of the organisation. Therefore, the epistemology of both autopoiesis theory and perceptual control theory is *constructivist*: an organism's knowledge should not be seen as an objective reflection of outside reality, but as a subjective construction, intended to help find a way to reconcile the system's overall goal of maintaining its organisation with the different outside perturbations that may endanger that goal.

For most non-cyberneticists, the word 'control' connotes the image of a central controller, an autocratic agent that oversees and directs the system being controlled. A cybernetic analysis of the control relation, such as the one of Powers, on the other hand, is purely functional. The 'controller' does not need to be embodied in a separate structural component. In fact, I have argued (Heylighen 1997) that the market can be seen as a *distributed* control system in the sense of Powers. The goal of the market system is to satisfy 'demand', by producing a matching 'supply', in spite of perturbations such as fluctuations in the availability of resources or components. Demand for any particular commodity is itself determined by the overall perception of availability of other commodities and the higher level goals or values (survival, quality of life, ...) of the collective consumer.

This is a negative feedback loop with amplification: small fluctuations in the supply will be sensed and translated into changes in the commodity's *price*, which is a measure for the difference between supply and demand. Small increases in price (perception) will lead producers to immediately invest more effort in production (action) thus increasing the supply. This will in turn decrease the price, thus reducing the deviation. Similarly, reductions in price will trigger decreased production and therefore decreased supply and increased price. Thus, the market functions to regulate the availability of commodities that the system needs. In spite of this unambiguous control function, no single agent or group of agents is 'in control'. The demand variable, which directs the process, emerges from the collective desire of all consumers, while the supply variable is the aggregate result of all actions by all producers. The control function is not *centralized*, but *distributed* over the entire economic system.

With a few generalizations, this analysis can be developed into a general model for the control mechanism of the social superorganism. Here, Miller's analysis can once more come to our support. Again, we must note that while Miller's functional subsystems are arranged more or less linearly, in the order of processing for information that enters the system, the mechanism as a whole is cyclic: the information that exits the system in the form of actions affects the environment, which in turn determines the information that comes in through perception.

Table 2

Functions of the nervous system (processing of information) in animals and societies

Function	**Animal**	**Society**
Sensor	sensory organs	reporters, researchers, etc.
Decoder	perception	experts, politicians, public opinion, etc.
Channel and Net	nerves, neurons	communication media
Associator	synaptic learning	scientific discovery, social learning, etc.
Memory	neural memory	libraries, schools, collective knowledge
Decider	higher brain functions	government, market, voters, etc.
Effector	nerves activating muscles	executives

Miller's first two subsystems fulfill Powers's function of perception: the *input transducer* brings information from the environment into the system, similar to the ingestor bringing matter into the system; the *internal transducer* plays the same role for information originating inside the system. The function of this information is to signal real or potential perturbations away from the goal (dangers, problems), and/or opportunities to achieve the goal (resources, tools). These dangers and opportunities may originate both inside and outside the system, but for simplicity we will discuss them together as if they all come from outside, thus merging 'input transducer' and 'internal transducer' into a single *sensor* function.

This can be motivated by the observation that a truly functional logic implies that we should not consider the actual physical location of a problem or opportunity, but its functional characteristic of being or not being under the control of the system. Remember our discussion of the immune system as the functional 'boundary' of an autopoietic system: internal renegades, such as tumors, are as much perturbations to the system as external invaders, such as pathogenic micro-organisms. Similarly, external extensions of the body, such as clothes, tools or vehicles, are as much under the control of the system as its own components and can therefore be functionally interpreted as parts of the system.

In the body, the sensor function is performed by the sensory organs: eyes, ears, nose, tongue and various cells sensitive to touch, heat and motion in skin, muscles and joints, but also by internal chemoreceptors for hormones, etc. In society, many components take part in sensing: the market, reporters, scientists, polling institutions, voters, and various automatic sensors such as seismographs, thermometers, and satellite sensing installations.

The next information processing function is the *decoder*, which transforms the incoming stimuli into internally meaningful information. In the control system model, this interpretation process functions basically to relate information about the external situation to the system's goals or values, thus making it easier to use this information as a guideline for action. This implies that information irrelevant to any of the system's goals is ignored or filtered out. The decoded information is then used by the *decider* subsystem to select a particular action or sequence of actions in response to the perceived state of the environment. In higher order control sys tems, where there is a complex hierarchy of goals and subgoals, the actual actions selected may have little to do with the present situation, but rather anticipate potential situations in an as yet far away and uncertain future (cf. Heylighen 1992a). Exploratory behavior is an example of such action that does not seem to have direct relations to the present situation and goal, although in general it helps the system to find new opportunities to achieve its goals. Only urgent danger signals will require immediate counteraction. In animals, both decoder and decider functions are performed by the brain. In society, they tend to be concentrated in political, scientific, legal and commercial institutions, although basic forms of interpretation and decision are distributed throughout the whole of society, as illustrated by market demand ‘deciding’ which types of commodities are to be produced, or voters deciding which political values should steer the country.

The next step consists in implementing the decision, that is, translating the information generated by the decider into a concrete plan and executing the corresponding actions. This is the task of the *effector* function. This function is absent in Miller's scheme, who proposes the encoder and output transducer functions instead. The reason is that Miller's decomposition hinges on the linear sequence of information entering the system, being processed and finally leaving again, not on the cyclical control function, where the only function of information is to help select the right control action. Although actions may be informative to other systems, they are not generally intended to transmit information, but to compensate for perturbations. Therefore, there is no *a priori* need for the encoding and output of information.

Of course, certain actions, such as speech, have a communicative intention. But this intended transfer of information is subordinated to the more general purpose of achieving the organism's goal. Typical goals of linguistic expression are to make another person do something (a command or request), to get specific information (a question), to get general feedback about one's own state (free expression), or to provide information that might help the other and thus indirectly – through reciprocation, social ties or kinship – help oneself. In such cases, Miller's encoder and output transducer are present as specialized subfunctions of the more general effector function.

In animals, the effector function is performed by motor neurons that activate muscles. In society, it is performed by 'executives' of various ilk, including government ministers, managers, engineers, drivers, and by automated systems that drive machines.

The nervous system also has its analogues of the metabolism's distributor, storage and producer functions. Miller's *channel and net* function is responsible for the communication of information between the various subsystems, such as sensor, decider and effector. In the body, this function is performed by various nerves, in society by communication channels such as mass media, telephone and post. Another destination for information circulating in the system is *memory*, where information about previous interactions is maintained to support future decisions. Unlike the storage function, memory does not simply accumulate incoming data chunks – the way a computer disk records bytes – but maintains a selective, ever adapting trace of correlations between various perceptions and actions so as to increase the effectiveness of decision-making when similar situations are encountered later. The function responsible for creating this network of associations is Miller's *associator*. In animals, associator and memory are distributed over the neurons in the brain. In society, memory is supported by written documents, libraries and databases. The associator function is performed among others by scientists, scholars and archivists.

EVOLUTIONARY DEVELOPMENT OF THE SUPERORGANISM

Evolution of cooperation

Although Darwinian theory provides a robust model of the evolution of individual organisms, the evolution of societies of organisms does not fit so obviously into that model. The main issue is the tension between individual selection and group selection. Darwinian theory predicts that if an organism is to choose between behavior that will promote its selfish interests, and behavior that benefits the group or society to which it belongs, then in the long term only the selfish behavior tends to be selected. The reason is that selfish individuals in an altruist group ('free riders') profit more from altruist behavior in others than the altruists themselves do. Therefore, altruist behavior tends to be eliminated. Yet, animal and human groups provide plenty of examples of altruism, *i.e.* behavior that contributes more to the fitness of others than to the fitness of the altruist individual. Several explanations have been offered for this development (see *e.g.* Campbell 1983; Axelrod 1984; Dawkins 1989; Stewart 1997). Since I have discussed this issue in depth elsewhere (Heylighen 1992b; Heylighen and Campbell 1995), the following paragraphs will merely sketch the main arguments.

The mechanism of group selection (groups of altruists being more likely to survive than groups of selfish individuals) seems rather unsatisfactory because of the free rider problem mentioned earlier. Yet, group selection has recently again become more popular (Wilson and Sober 1994), in part because of the observation that not all behaviors beneficial to the group have a high cost to the altruist individual. The most popular explanation, which is at the base of the sociobiological approach, is kin selection: the principle that it is evolutionarily advantageous to be altruist towards individuals that carry the same genes ('kin'). This mechanism seems sufficient to explain insect societies, where all individuals are closely related to each other via their shared mother (the 'queen' of the nest). Another popular mechanism is reciprocal altruism, or 'tit for tat' (Axelrod 1984), but this seems insufficient to explain cooperation in large societies where there is often no opportunity for reciprocation.

To explain the emergence of human society, for me the most compelling mechanism seems to be cultural conformism or 'meme selfishness' (Campbell 1982; Heylighen 1992b; Heylighen and Campbell 1995): if a cultural norm ('meme') prescribing altruism manages to spread over a group, conformist pressures will make it very difficult for would-be 'free riders' to deviate from that norm. Since different groups in general follow different norms, there will be a cultural group selection promoting the more altruist norms, which have the strongest benefit to the group as a whole. Stewart (1997) has proposed a more general mechanism, where a 'manager' (which may be a dominant individual, a subgroup, or a cultural norm) takes control of a group for selfish purposes, to appropriate part of the group's production, but undergoes selection for promoting altruistic behavior within the group: groups whose manager does not efficiently suppress cheating and free riding will be less productive, and thus their manager will be less fit.

Whichever its precise origin, once a stable pattern of cooperation had been established as a basis for human society, it quickly led to a division of labor. Division of labor is based on the principle that if individuals specialize in carrying out particular tasks, they can be more efficient. However, if an individual is exclusively busy producing one particular type of commodity or service, then that individual will be dependent on reciprocation by others for providing the other resources (s)he needs. Therefore, division of labor can only evolve on a solid basis of cooperation. But once the process has started, division of labor will spontaneously increase, driven by a positive feedback mechanism, as illustrated by Gaines's (1994) computer simulation: individuals who were successful in providing a particular type of service – because of opportunity, competence or simply accident – will get more requests for that type of service, and thus get the chance to develop a growing expertise in the domain. This in turn will increase the demand for their specific service, stimulating them to further specialize. For example, an individual who happens to live near fruit trees may find it easier to make a living by exchanging fruit for meat and other resources than by participating in the communal hunting and gathering, and therefore will tend to invest increasingly more time, attention and resources in developing fruit harvesting capacities.

The increasing division of labor entails an accompanying increase in mutual dependence and therefore cooperativity. *Cooperativity* could be defined positively as probability or dependability of cooperation, and negatively as lack of cheating or free riding. This property of social systems is related to the concept of 'social capital'. It is implicit in the legal system, the organisation of the economy, and the unwritten rules which individuals follow in their interactions with others. For example, a society in which no one trusts anyone and everybody is constantly trying to take advantage of the others without doing anything in return, has low cooperativity. More concretely, the failure of the market to quickly produce economic growth after the fall of communism in the former Soviet states may well be due to a lack of cooperativity in these societies: