DECENTRALIZED NETWORK STRUCTURES IN THE SCIENTIFIC COMMUNITY: PROBLEMS AND PROSPECTS

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ABSTRACT. Despite important recent achievements in various fields of science ranging from genetic engineering to quantum physics and space research, a serious challenge for the present-day world is the necessity to urgently reform the organization of the scientific community in order to drastically increase its efficiency and productivity and to avoid serious problems exemplified by unjustifiable procrastination in the development of a COVID-19 vaccine that has had disastrous global consequences. Such problems are particularly prominent in countries like Russia and China, where the scientific community has been struggling with a systemic crisis. In this work, decentralized networked patterns of teams of researchers, experts, and science entrepreneurs are suggested. One possible scenario is the *hirama (High-Intensity Research and Management Association)*, i.e. a decentralized network structure with several partial creative leaders. In addition, living nature has created at least seven different scenarios (paradigms) of network structures during the course of its evolution. All these paradigms are potentially applicable to teams dealing with creative scientific work and can be efficiently combined to develop novel organizational patterns for scientific research and related business projects.

Apart from scientific research activities per se, network structures can be used in environmental, educational, and health care institutions. The establishment of digital platforms in the modern informational age is expected to significantly promote the development of decentralized network structures (DNSs). This process is also facilitated by decentralized blockchain-based transactions, especially if virtual currencies are used. In this work, it is suggested that the development of network structures and the optimization of their operation is to be achieved by setting up guidelines-providing networks denoted herein as *chaperones*.

Chaperones are expected to promote the development of large-scale influential *meganetworks* that should constitute the backbone of the emergent networked (*reticular*) social and economic system. The development of this promising innovative system should be facilitated by such practical steps as establishing an innovative Research Institute for Network Structures (RINS), a Networks-Promoting Committee (empowered to suggest new laws that grant a legal status to decentralized networks), and a large number of counseling commissions and incubators for new developing DNSs, especially for those dealing with scientific R & D activities.

Key words: decentralized network structures (DNSs), hierarchies, (quasi-)market structures, hirama, biological network paradigms, social chaperones, meganetworks, network-based (reticular) social and economic system.

Abbreviations: ANN, artificial neural network; DE, digital economy; DNS, decentralized network structure; hirama, High-Intensity Research And Management Association; NPC, networks-promoting committee; PBL, project-based learning; R & D, research and development; ; RINS, Research Institute for Network Structures; SME, small or medium-sized enterprise.

CONTENTS

INTRODUCTION

As emphasized in the Abstract, it is imperative that the efficiency of scientific research and development (R & D) activities should be substantially increased in the present-day world. Beyond any doubt, very important achievements have already been made in an extremely wide spectrum of scientific disciplines. This has enabled humankind, for instance, to send probes to distant planets and to modify the genetic make-up of various living organisms including, notably, humans themselves. However, there are still serious problems and challenges faced by the scientific community, and they affect even the progress of scientific research in the comparatively successful “First World” countries (Western Europe, North America, and Japan), to say nothing about the situation in post-communist countries where reforming the organization of scientific research and related commercial projects is one of the top priorities. The present work is focused on organizational patterns that, far from being a panacea, are nevertheless expected to significantly promote various kinds of science-based R & D projects.

These special organizational paradigms are based on nonhierarchical, horizontal, cooperative relationships among scientists, scholars, and, most frequently, also business people. Such predominantly horizontal distributed network structures are capable of efficiently operating in the capacity of creative interdisciplinary research teams and labs, groups of scientific experts, scientific research results-using SMEs, or scientific educational institutions.

In this work, *decentralized network structures (DNSs)* dealing with science-based research and development (R & D) activities are contrasted with more conventional *hierarchical structures* that are characteristic of a majority of scientific research institutions. Hierarchies with deans/provosts at their top are typical of traditional universities and colleges; directors are at the pinnacle of the research institutes of national academies of science. In contrast, DNSs are typically based on the *split leadership* principle (see Figures 2 and 6 below). They frequently have several partial, temporary or situational leaders; importantly, they are based upon the principle of ongoing *cooperation* among their members. Therefore, network structures differ not only from hierarchies but also from *(quasi-)market structures* that are predominantly characterized by *competition* and not cooperation among their agents (e.g., business firms).

The author considers the main goal of this work to be demonstrating the potential of decentralized network structures in terms of modernizing the work of the scientific community, including scientific research per se, its business applications with respect to biotechnology, nanotechnology, IT, pharmaceutics, and space research, the training of personnel, and the activities of scientific experts. The author believes that this relatively short work sums up a large part of the results of theoretical work carried out for about 25 years; therefore, the present work can be considered as an interim progress report concerning the author's scientific career.

Section one. DEFINING DECENTRALIZED NETWORK STRUCTURES IN CONTRAST WITH HIERARCHIES AND (QUASI-)MARKET STRUCTURES

The term *network structure* (or just network) has attracted much controversy; it is used in at least two different meanings in scientific literature. In the wider sense, a network is defined as any "set of items, which we will call vertices or sometimes nodes, with connections between them, called edges" (Newman, 2003, p.2), and this definition has been adopted by a large number of scientists and scholars around the world. When defined this way, the term "networks" has already been applied both to human society and to the biological realm, and a large number of works comparing networks (in this broad sense) in these two types of systems have been published (see, e.g., Barabasi, 2002; Newman, 2003, 2012; Almaas et al., 2007).

However, since the 1980s, another interpretation of the term "network structures" has been relatively widely used as well, particularly in the social sciences (Powell, 1990; Castells, 1996, 2004; Börzel, 1998; Meulemann, 2008; Kahler, 2009a, b). According to this more specific definition, not all sets of connected items may be called networks. *A network lacks a central pacemaker (leader, dominant element), and its activities and collective behaviors result from cooperation among its members often involving a number of partial leaders with limited power and competence*. This is exemplified by the World Wide Web, which is largely based upon this organizational principle.

In this work, the term "networks" is predominantly interpreted in the latter sense, except for a part of the Historical subsection.

The characteristics of a decentralized network structure are to be considered in comparison to other types of structures that are denoted as (1) *hierarchical (vertical, pyramidal) structures* characterized by a single dominant activity center (central leader, pacemaker); and (2) *(quasi-) market structures*[1] dominated by competitive, rather than cooperative, interactions among the actors involved (see Figure 1). This work is interdisciplinary because the three kinds of

[1] Analogs of markets, i.e., competition-based structures existing in human societies lacking true market relationships as well as in communities formed by various biological species, are referred to herein as *quasi-market structures* (Oleskin, 2014). The term "quasi-market" is used in a different sense by some economists: it denotes interactions between former departments of a firm that have acquired some degree of autonomy and entered into contract-based relations.

organizational structures that are widely spread in human society, including the scientific community, are compared to similar structures in living nature.

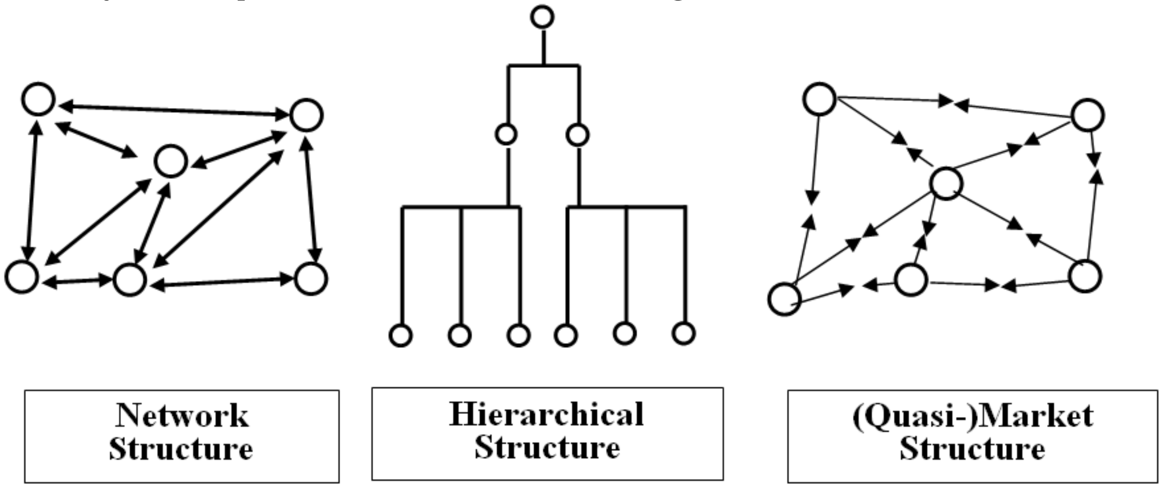

Figure 1. Comparing decentralized networks, hierarchies, and (quasi-)market structures. ↔, cooperation; →← competition

1.1. Historical. The term network is based on a very ancient concept. Both the broader and the more specific meaning of this word were actually familiar to human society during the course of its history. Nevertheless, to see a network as a decentralized cooperative system would more closely reflect its original, literary, meaning. A network, when defined according to this earlier meaning, can be likened to a fishing net. By invoking this image, we can establish some important features that a network has, according to its modern scientific meaning:

1. *Decentralization:* A fishing net or a trawl obviously lacks a central node.
2. *Cooperation among a network's elements*, i.e., meshes that collectively perform their function (catching fish); the cooperation among the net's elements (meshes) is based on its *connectivity/cohesion*: the meshes of a fishing net are connected by threads or ropes
3. *Self-similar /Fractal geometry* (any given part is a reduced copy of the whole structure). Part of a fishing net is a fishing net per se: it can be used for catching fish, albeit smaller ones. In other words, a net is a multilevel structure; it may be broken down into smaller nets and can form a part of a larger network's structure.

A network's cardinal properties: decentralization, cooperation, and self-similarity have acquired culturally-determined meanings during the course of the history of human society. Their spectrum was extremely vast, and literary meanings were imperceptibly transformed into figurative or metaphorical ones by various cultures. Even the network in its original meaning, the fishing net, acquires metaphorical and allegorical overtones. "And Jesus, walking by the Sea of Galilee, saw two brethren, Simon called Peter, and Andrew his brother, casting a net into the sea: for they were fishers. And he saith unto them, Follow me, and I will make you fishers of men. And they straightway left their nets, and followed him" (Matthew 4:18-20, Bible, 2011).

In practice, irrigation systems with their canals and reservoirs actually implemented the fishing net model; taxes were levied and territories were defended using the structural pattern of a fishing net (Startsev, 2011).

Historically, the mathematician Leonhard Euler who lived in Königsberg in the 18th century was one of the first researchers to use the network approach in science. He invoked graph theory, a subfield of mathematics that is very closely related to network analysis. Euler tried to solve a problem concerning seven bridges in Königsberg: to find a walk through the city that would cross each bridge once and only once. Euler drew the conclusion that the problem has no solution.

The term network was used in the humanities for describing relationships between individuals and groups in society, starting from the turn of the 20th century. The work by Georg Simmel (1908), the founder of the formal school in sociology, already contained the term "social network". The anthropologist Alfred Radcliffe Brown pointed out that "direct observation does reveal to us that… human beings are connected by a complex network of social relations. I use the term 'social structure' to denote this network" (Radcliffe-Brown, 1930). He urged other anthropologists to conduct systematic studies using the network approach.

"Alfred Radcliffe Brown saw the social structure as a network of relations, while his student and colleague Lloyd Warner explored network cliques in his community studies. Some of Warner's ideas had been sharpened during his involvement in the famous Hawthorne studies, where the researchers had been struck by the similarities between the electrical wiring diagrams that littered the Hawthorne factory and the patterns of connection among the workers who produced this wiring" (Crossley et al., 2009, p.2).

In the 1930s and the 1940s, the psychiatrist Jacob Moreno and the psychologist Helen Jennings depicted, in the form of network structures, patterns of inter-individual interactions in their research concerning informal leadership in the US prison Sing-Sing and the Hudson School for Girls (Moreno, 1932; Jennings, 1943). Also of interest was the work of Elton Mayo and his colleagues concerning social networks formed by factory workers in the 1930s in Chicago as well as the mathematical models of Anatol Rapoport, as emphasized by Newman (2003, p.5). The "Southern Women Study" conducted in 1939 and published in 1941 dealt with 18 women from the American south that attended 14 social events. In the form of a network, the authors showed which of the women attended which events (Davis et al., 1941; quoted according to: Newman, 2012, p.380). A rigorous meaning of the term network was used in the social sciences beginning with the work of J. A. Barnes (1954).

More recently, this area of research has received considerable attention, and there have been a large number of publications in areas ranging from theoretical physics to computer science, the social sciences and the humanities, as well as the life sciences. "Increasing globalization has seemingly interconnected everything, our communication networks (e.g. internet, mobile phone) and transport systems span the globe, the economic integration of nations and communities becomes ever closer and more complex with a growing number of multinational organizations and environmental problems transcending national boundaries. The fact that our world is becoming more and more interconnected has led to an exponential interest in understanding networks" (Krause et al., 2009, p.967).

1.2. Introductory discussion of the role of decentralized network structures in the example of networked business enterprises. Before directly addressing the applications of *decentralized network structures (DNSs)* to scientific research and development activities, a short excursion should be made to the world of business.

It was in the realm of business that network structures received much attention in terms of sociology and management theory as early as in the 1980's (see, e.g., Chrisholm, 1989; Powell, 1990). Formerly, the sphere of business was believed to include only hierarchical corporate structures (firms) and markets. Firms were the enclaves of planned economy in the market relations-dominated business world. By the early 1980s, it became obvious that the sphere of business also contained a third element, network structures. “In markets, the standard strategy is to drive the hardest possible bargain in the immediate exchange… Within hierarchies, communication and exchange is shaped by concerns with career mobility – in this sense, exchange is bound up with considerations of personal advancement… *In networks, the preferred option is often one of creating indebtedness and reliance over the long haul*” (Powell, 1990, p.302; the order of the sentences quoted is changed; emphasis is added – O.A.). Of paramount importance in economic terms are the following features of network structures:

- Joint control of all network members over the network’s activities,
- Common ownership of their property,
- Common goals shared by all the members.

Decentralized network structures in human society may represent intentionally established creative teams, e.g., think tanks associated with governmental institutions. Nonetheless, network structures can also arise spontaneously, provided that their members have common concerns and interests, shared goals and values, and, frequently, spontaneously developing collective behavioral norms. In sum, all these unifying factors can be construed as the *matrix* of a network. The immaterial matrix promotes the consolidation of network structures in the absence of a central leader. In modern-day society, virtual information transfer channels indisputably facilitate the establishment of nonhierarchical common interests-based associations as exemplified by the *GreatCooksCommunity* or the teams of environmental activists. Another example is provided by the *AntEra Association* (2019) that brought together people suffering from chronic diseases such as rheumatism and also enlisted health care workers interested in helping them. The distributed network structure of this Association helped it attain the multi-aspect goal of healing and rehabilitating the people involved. The founder of the AntEra Association Alexander Krel’ emphasized that the aid provided by AntEra was not confined to medical treatment. It positively influenced all aspects of the patients’ lifestyle in social, economic, cultural, and spiritual terms .

Currently, it can be predicted that new spontaneous decentralized networks composed of coronavirus-infected people will very soon spread around the globe. These people are “soulmates” with common interests and some shared attitudes towards the rest of society.

Spontaneous networks arise in the economic sphere under the influence of virtual currencies and the blockchain system.

Despite a lack of central leadership, decentralized networks are consolidated by common goals and shared behavioral norms that are often supplemented with specific rituals and distinctive features (e.g., uniform or dress style) displayed by network members. These cohesion-promoting factors can be denoted, to re-emphasize, as the *network matrix.* Network structures find application in small or medium-sized enterprises (SMEs) as well as in large transnational companies that lack central headquarters. Similar DNSs are used in various clubs, charitable foundations, bohemian teams of artists, and even local governance bodies as exemplified by the short-lived Republic Sivtsev Vrazhek that was based on a condominium in one of the streets of Moscow in the 1990s. Network organizational principles can be successfully implemented by scientific research labs, social movements, and political organizations; DNSs (networked teams) can be set up by students in the classroom to promote interactive learning/teaching (see Section 6).

The fact that such network structures are decentralized, i.e., have a split leadership pattern with several hubs (partial leaders) sharing the responsibility for their work, results in important managerial changes:

- *Wide specialization* of its members: instead of narrowly focused specialists, there are generalists who cope with the whole task (mission, role) carried out by the network, tending to work as a single team;
- Efforts to *promote informal personal relationships* among network members (individuals or groups);
- *Management style* focusing not only on attaining the goals pursued by a network structure, but also on satisfying the needs of the people involved in this network;

Importantly, network structures may be small (approximating the size of a primitive hunter–gatherer band) or large. With large networks, the multilevel (fractal) organization of network structures becomes obvious: a network structure consists, in turn, of smaller network structures.

Regardless of whether networks develop spontaneously (and their members seem unaware of their belonging to a DNS) or are purposefully established by, e.g., social engineers, the people that join them typically expect the following:

1. A *lack of hierarchy* with the equalization of the members' social ranks.
2. A *policy enabling the members of a social network to overcome loneliness* and even to play the role of partial (temporary, situational) leaders and to develop a feeling of belonging within the framework of a coherent social group (e.g., a team of enthusiasts); the networked group is expected to actively supports each of its members while respecting their individuality.

Comparison of network structures and more traditional social hierarchies typified by bureaucracies reveals that a centralized hierarchy can outperform a network in terms of "efficiency criteria such as speed, message count, and frugal use of resources… The network lacked a central coordinating mechanism and spent more time negotiating procedures" (van Alstyne, 1997).

However, it is important to re-emphasize the creative potential of network structures, particularly with regard to inchoate projects and innovative ideas. Both the relatively slow tempo of a network and its creative potential are demonstrated below (see Section 6) in the example of networked and hierarchical student teams in a classroom. Innovative ideas generated in hierarchies are "more likely to be discarded on the grounds that the central person was too busy, that the innovation was too bothersome to implement, or that current practices required no improvement" (van Alstyne, 1997). Moreover, "persons in the network structure are apt to value their participation more and be much happier with their experience. The one exception is the central person in the hierarchy who was generally quite happy" (Ibid.).

In sociological terms, decentralized nonhierarchical cooperative networks tend to evolve into primary groups (*Gemeinschaften* in the words of Ferdinand Tönnies (1988), a classical German sociologist). In his view, a *Gemeinschaft* is similar to a family: interpersonal relations inside it resemble parent–child, husband–wife, or brother–sister bonds. Human relationships are based upon reciprocal attachment and support, as well as the feeling of belonging to the group and self-identification with it. Any personality in a *Gemeinschaft* is regarded as unique, and the whole group is significantly changed with the appearance or disappearance of a single member. In contrast, a *Gesellschaft* (also termed "secondary group" or "society") envisions people only as incumbents of partial, and often temporary, social roles. While in a *Gemeinschaft*, people live together; in a *Gesellschaft*, they just coexist as temporary "fellow travelers", business partners, service clients, and so on (Tönnies, 1988).

Bureaucracies belong to secondary groups (*Gesellschaften*) where people interact in conformity with official regulations because they are "coworkers and not friends". A different situation is typical of a networked organization. Formal interactions are supplemented by informal relationships involving personal likes and dislikes, sentiments, and informal leadership that is typically partial and situation-dependent. Even networks only pursuing the goal of doing a practical job for a limited period of time, nevertheless, tend to evolve into quasi-communes. From the psychological viewpoint, virtual interactions among online social network users, e.g., on the Facebook or MySpace websites, promote mutual trust, self-diclosure, multi-aspected communication, and even intimacy, provided that virtual network structures robustly function for a sufficiently long time.

Since communication among network members is not limited to business, and since it tends to become informal and deals with various aspects of each member's life, promotes a multifaceted approach to the tasks faced by the network. In similar fashion, neural networks in the brain try more than one strategy to deal with a problem, which often implies that the active neural subnetwork dealing with this problem activates a number of other subnetworks within the brain. In network structures made up of scientists, an analogous strategy promotes an integrative, interdisciplinary approach to the subject of their research and facilitates innovative thinking strategies as well as networking among several originally independent teams of researchers.

In contrast to hierarchies such as bureaucracies that typically prefer narrow specialization and perform a limited number of professional/social functions, many decentralized networks tend to combine a number of different activities. The same network structure may simultaneously or consecutively function as a research lab, charitable foundation, commercial firm, educational center, team of artists, political pressure group, etc., depending on the aspect of its versatile activities that comes to the forefront in a given situation. Importantly, the operation of most DNSs does not boil down to any single function; it is a multifaceted social structure which tends to promote strong informal relationships among its members.

The leadership of many countries around the globe is aware of the potential importance of decentralized social organization patterns. This is exemplified by China. Despite the highly centralized political system, the Chinese leadership took several important measures, starting from the 1970s, to grant considerable autonomy to a number of leading research institutes and educational centers including universities and colleges. Subsequently, these measures were stipulated at the 4th National Conference on Higher Education (1992) that adopted the Outline Program for Educational Reform and Development (Xiaohong & Verhoeven, 2004). The decisions of the Chinese Politburo and other governmental bodies aim to promote decentralized networks that develop within the context of digital economy including blockchain systems. Special attention is paid to bridging the widening gap between the hierarchical state apparatus with a centralized banking system – and various kinds of decentralized economic activities involving the Bitcoin and other virtual currencies. In order to overcome the gap, the recently established Cyberspace Administration of China has instituted a national blockchain-regulating committee. In China, DCNs are both promoted and harnessed by the central government that makes them transparent in order to further its political interests in the digital world.

Section two. IMPORTANT TYPES OF DECENTRALIZED NETWORK STRUCTURES

2.1. Hirama. An introductory example of DCNs is provided by the organizational pattern called the *hirama (High-Intensity Research and Management Association)*, This is a creative team that is set up for tackling an interdisciplinary project exemplified by *Monitoring the State of Plant Ecosystems*. This general project is broken up into more specific subprojects (Oleskin, 1996, 2014a, b; Oleskin & Masters, 1997; Oleskin & Shenderov, 2020). For instance, the aforementioned project includes the following subprojects (Fig. 1):

- *Assessing the Pollutant Concentration and the Radioactive Background*
- *Determining the Intensity of Photosynthesis and of Light and Dark Respiration of Plants*
- *Evaluating the Prospects for Ameliorating the State of the Ecosystems*.

Despite subdividing the project into subprojects, the network is not broken down into subnetworks. Its members work, in parallel, on several (ideally on all) subprojects. The subproblems should, therefore, overlap and provide for a broad interdisciplinary vision of the network's focus. Roles or functions in this network structure are not fixed or defined as with the "offices" in a Weberian bureaucracy. Only one person, the partial subproject leader, is attached to a particular subproject. The person collects ideas on this subproject. A partial leader in a hirama is a variation on the more general theme of a *network leader* in human society, i.e., a person with intellectual, financial, material, communicative, informational, or other assets that are important in terms of business but who is not the boss.

A hirama also has a *psychological leader* who promotes efficient work on all subprojects and helps other partial leaders interact with one another, preventing internal conflict. The psychological leader provides support, advice, and psychological help that is often sought by other members; he or she creates an atmosphere that promotes efficient work on all subproblems and helps other partial leaders interact with one another, mitigating or—still better—preventing internal conflict. Otherwise, when partial "leaders do not recognize each other's leadership, the group can literally be torn apart". By contrast, if they "recognize one another as leaders, they should be better able to synchronize their leadership efforts so that decision-making and action are more effectively channeled within the group" (Mehra et al., 2006, p.235).

In addition, a hirama typically includes an *external leader*. The individual with this role is responsible for propagandizing hirama-promoted ideas, establishing contacts with other organizations, and shaping the group's pastime and leisure activities, thus contributing to the development of informal loyal relationships among members. Hiramas are free to make alterations in the network's organizational pattern. Additional leadership roles can be introduced such as:

- A *commercial leader* responsible for searching for sponsors and grant opportunities and for marketing and other profit-making activities
- An *organizational leader* who is particularly important while a hirama-type network is organizing its work and legalizing its status
- A *spiritual leader* (a "guru"). The operation of network structures depends on unitary spiritual values, often implying collective attempts at attaining certain ideals. This conceptual basis can be personified by the "guru" image. Importantly, the spiritual leadership should not develop into an authoritarian dictatorship, which would run contrary to the non-hierarchical principle underlying a network structure. To prevent this, hiramas may prefer a legendary guru or a long deceased famous person like Emiliano Zapata, a hero of the Mexican revolution in 1917, whose name is perpetuated by the networked Zapatista movement in present-day Mexico.

The hirama organization pattern is used, with certain modifications, for setting up interdisciplinary scientific research teams, commercial enterprises, and various communal structures. This structure is shown in Figure 2.

The hirama is not the only organizational option available for DNSs.

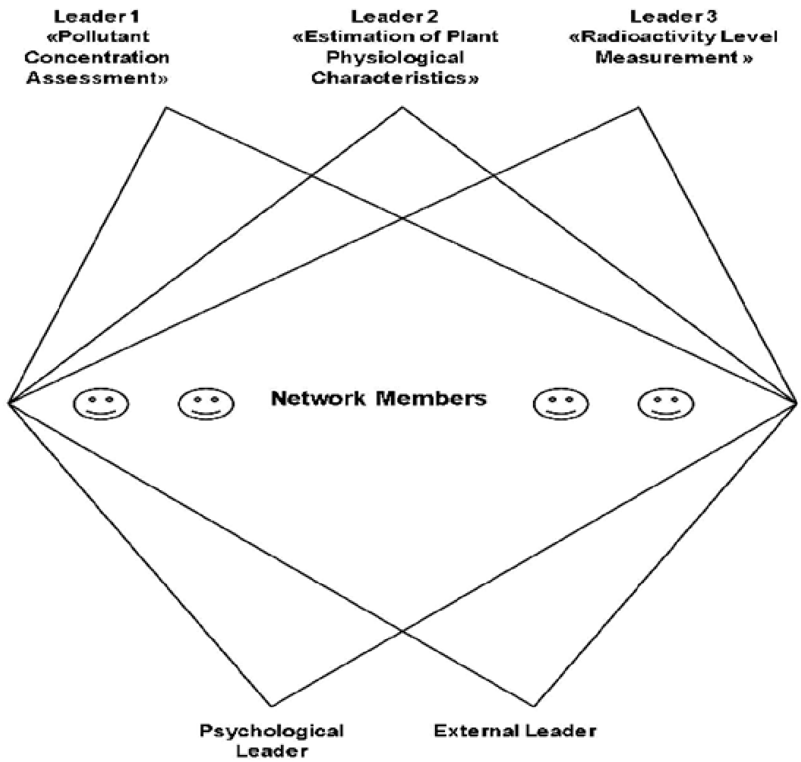

Figure 2. A hirama-type network structure applied to the assessment of the state of plant resources (see text for explanations)

2.2. Alternative scenarios of network structures: biological paradigms. A large number of biological systems are decentralized and cooperation among their elements (living cells, individuals, their groups, etc.) prevails over competition. For instance, microbial colonies or biofilms consist of a large number of microbial cells. They do not contain leader cells but the lack of a single controlling center does not prevent effective coordination of the cells' behavior.

Organizational scenarios (paradigms) based on patterns used by living nature are applicable to network structures set up in human society for various purposes, including creative teams dealing with interdisciplinary, often fuzzy, issues and conducting brainstorming sessions, student groups in the classroom (if the interactive teaching scenario is used, see below), small networked business firms, groups set up during psychotherapy sessions, political structures, and civil society associations. Of special interest, in the author's opinion, are innovative modifications and combinations of network structures inspired by living nature.

2.2.1. Cellular (microbial) paradigm. Decentralized network structures are formed by diverse types of cells, including both free-living (microbial) cells and those forming a part of the tissues of multicellular organisms. In the absence of any leaders, the coordination of cell behavior in the interest of the whole network is largely due to (i) cell-cell contacts that represent cytoplasmic bridges or points at which the outer membranes of several cells fuse, or, alternatively,

(ii) chemical communication signals that spread within the whole network (colony, biofilm). Cell networks frequently contain the *matrix*, a structure composed of biopolymers that cements all cells in the network structure (reviewed, Oleskin, 2014a, b; Oleskin & Shenderov, 2020).

An analog of the cellular paradigm in human society is a DNS that is characterized by a tendency towards the formation of collective “superintelligence” from the individual minds of network members on the basis of a set of unifying explicit and implicit ideas and behavioral norms – of the intellectual matrix that underlies the network, in an analogy to the material extracellular substance in which cells are embedded in a colony/biofilm. The development of this network-wide matrix diminishes the importance of individual differences among network members. For all network members, identification with the whole network prevails over their individual self-identification. Extrapolating the cellular paradigm to human society implies the cohesion of a nonhierarchical creative team based on psychological techniques that emphasize the importance of network-level values, goals, and creative interaction among network members despite their individual differences.

2.2.2. Modular (“cnidarian”) paradigm. This paradigm is implemented in biological systems that consist of uniform structural units (modules); such systems are distinguished by the prevalence of a flat (leaderless) network organization pattern. A classic example in the animal kingdom is provided by cnidarians and bryozoans. Their organisms consist of repetitive units (zooids), e.g., polyps or medusae (jelly-fish), that are connected by a single stalk (the coenosarc). In this typically decentralized structure, each zooid performs actions (e.g., contracts and causes the liquid inside the stalk at its attachment site to move) that only exert a weak effect on the whole network that includes numerous zooids. However, a single zooid’s impact is potentiated if its behavior happens to be in unison with the behavior of a majority of other zooids in the same modular network structure. For example, a sufficiently large number of zooids that synchronously propel liquid suppress those with a different pumping rhythm that decelerate their movement in conformity with the colony’s predominant rhythm (Marfenin, 2002, 2009).

In contrast to the cellular paradigm (see 2.2.1 above), the modular paradigm implies that the individuality of each network element (module) is retained to a much greater extent, even though all modules are connected by a single stalk (coenosarc). In similar fashion, a common ideology has the power to unite all members of a close-knit network in human society. Network elements compete, and not only cooperate, with one another. Therefore, the modular paradigm implies a contradictory situation that promotes creative tension and stress: network nodes (members), despite their competition, all attempt to make progress in terms of the network’s project. A prerequisite for this cooperation despite competition is that they all share important values and goals, which represent an immaterial analog of the stalk that connects the zooids of colonial cnidarians.

2.2.3. Rhizome paradigm. This type of networks is characteristic of fungal mycelia, including those forming a part of mycorrhiza systems (based on a symbiotic relationship between a fungus and a plant), and of the rhizomes (rootstocks) of many plants. The rhizome concept was developed in philosophical terms by Gilles Deleuze and Felix Guattari in their prominent book *A Thousand Plateaus* (2004[1980]). They asserted that the rhizome in its metaphorical philosophical meaning has no beginning, no end, no center and no central principle. In contrast to the modular paradigm (see above), a rhizome-type network cannot be subdivided into nodes (vertices) and links (edges) that connect them, integrating the nodes into a whole colony. For instance, a fungal mycelium consists of links only, i.e. of filaments (hyphae) as uniform components of the whole mycelium on which organs such as rhizoids or fruiting bodies can develop. “By branching and fusing with other hyphae, the hyphae form a network-type structure known as the mycelium” (Kück et al., 2009, S.4).

This paradigm incorporates several principles that are of considerable social importance. Each hypha in a mycelium is a linear one-dimensional structure. Each of its parts (each cell in a septate hypha) only interacts with two adjacent parts (cells). In business, an analog is a transaction based only on vertical interactions along the *supplier –– producer -- wholesale dealer -- retail dealer -- customer* pathway. As mentioned above, neighboring hyphae can branch, and their side branches can fuse at some points. Hypha branching and fusion are analogous to the establishment of network-type connections that are beyond the routine vertical pathway; for instance, suppliers can be directly connected to dealers (bypassing the producer); alternatively, several suppliers or dealers can come into direct contact and cooperate. The establishment of direct horizontal links within the framework of a network structure that includes suppliers, producers, and dealers makes it possible to customize the production.

Another socially relevant feature of many rhizome-type networks is their capacity to exist in two different forms, as a mycelium and as a group of separate yeast-like cells and, moreover, to interconvert between the two forms. This feature of rhizome-type networks, reminiscent of the quantum—wave dualism that is characteristic of photons in terms of quantum physics, can inspire, for instance the developers of dynamic business network alliances with changeable organizational forms.

2.2.4. Equipotential (“fish”) paradigm. Network structures that conform with this paradigm are characterized by a completely flat, leaderless pattern (Radakov, 1972; Pavlov & Kasumyan, 2003). Examples are provided by schools of many fish or marine invertebrates (*Echinodermata* and cephalopods) as well as by flocks of some birds and groups of whales. In the absence of a permanent leader, it is a chance individual that is the first to swim in a moving school; it is soon replaced by another individual, as if this were a role-playing game in an interactive classroom (see Section 6). In schools of young pollacks, the time during which an individual “leads the way” varies from a fraction of a second (0.25-0.5s) to several seconds. Thereupon, “the fish is located in the middle or even in the rearmost part of the school” (Radakov, 1972, p.86). Large fish (e.g., salmon) schools tend to separate into relatively independent small fish clusters (Croft et al., 2005), although there is also the opposite trend favoring the merging of small schools into larger ones. There are data that fish within one school or especially within .one small cluster are similar in terms of their individual features (size, color, sociality, etc.).

The tendency toward minimizing individual differences and equalizing social ranks that is characteristic of an equipotential, leaderless fish school should find application in network structures in human society; this paradigm can be used, for example, in network business enterprises.

2.2.5. Eusocial (“insect”) paradigm. This biological paradigm holds much promise in terms of social network structures, and it can be considered in the example of ant, bee, or termite societies. Eusocial network systems are characterized by a high degree of functional differentiation of their nodes (individuals) and quasi-organismic(supraorganismic) properties as well as by the formation of specialized “project teams” and permanent functional groups. Due to the existence of hierarchical dominance–submission relationships within eusocial systems, they are to be considered partly hierarchical systems. Temporary worker teams are set up for specific purposes, such as foraging or anthill building, and they are hierarchical structures controlled by a team leader (Figure 3).

Figure 3. Team formation in the colony of the ant *Camponotus socius*. The leader recruits the whole "team" by laying a long-lasting orientation trail and a short-lasting recruitment signal. The scheme is based on a modified picture (Hölldobler & Wilson, 2009, Figure 6-24). Reproduced by permission from the work The Superorganism: The Beauty, Elegance, and Strangeness of Insect Societies. Hölldobler, B. & Wilson, E. O. New York: W.W. Norton. Copyright © 2009 Bert Hölldobler & E.O. Wilson.

However, hierarchies are embedded in a predominantly network-type organizational environment. Hierarchical worker teams form part of a larger decentralized network structure. Workers that are not involved in the activities of specialized temporary hierarchical teams belong to the relatively inactive pool of generalists. The pool can be mobilized in a force-majeure situation for the purpose of doing urgent work. Eusocial systems are multilevel structures: they represent networks consisting of hierarchies made up of networks that, in turn, consist of hierarchies (see Zakharov, 1991, 2005; Hölldobler & Wilson, 1990, 2009, 2010).

In human society, analogs of eusocial network structures are exemplified by creative teams with temporary leaders that constantly interact with non-specialized network members within higher-order networks such as, e.g., small teams of environmental activists that combine to deal with large-scale projects The adherents of antiglobalism or alter-globalism that organized effective protest action against the IMF and the World Bank, as well the related Zapatista movement in the south of Mexico, compared political networked movements to neural networks (see below) and, to a larger extent, to the social structures of insects such as ants. "The ants can teach us that by working locally and continually sharing our local stories globally, by connecting everything and creating a plethora of feedback loops, we don't need to – indeed cannot — 'organize' the global network, it will regulate itself, swarm-like, lifelike, if we develop the right structures and conditions" (Networks, 2003).

2.2.6. Neural networks. This paradigm is typical of structures containing neurons (nervous cells), such as the nervous system including the brain. In contrast to many other biological networks, neural networks are predominantly coordinated via contact (synaptic), rather than distant, interaction between their nodes (neurons or their analogs). An important feature of decentralized networks in general, their capacity for collective information processing and decision making as well as collective learning and cognitive activities, is particularly prominent in neural networks. "…Neural networks can create the image of the whole object based on its fragments" (Oleskin, 2014a). From the systems theory viewpoint, it is of particular interest that neural networks combine networked and hierarchical organizational scenarios as well as parallel and serial information processing. Such networks are capable of constantly modifying their own structure to adapt it for solving specific problems. They are characterized by considerable efficiency and reliability: if some of their parts are faulty, the whole structure can still operate because of the existence of many parallel links among its elements (neurons or their analogs) that are used as bypasses. The organizational principles of such networks are simulated in artificial neural networks (ANNs) such as perceptrons, cognitrons, etc.

The ANN developed in the seminal work by McCulloch and Pitts (1943) contained three types of processing elements (artificial neurons): (1) several input units that perceive external information; (2) several hidden units that process the information obtained from the input units; and (3) a single output unit that is connected to all hidden units; it generates the output signal of the whole neural network.

McCulloch and Pitts' network was substantially modified as neural network theory was developed with the aid of research on real-life neural networks including those of the human brain. The classical perceptron that was designed by Rosenblatt (1957) contained several output units where the data processed by the hidden layer were summed up. Interestingly, the structure of a perceptron (Figure. 4, A) is similar to that of a human social network such as a hirama (Figure 2) that includes several partial creative leaders that collect and sum up ideas suggested by network members. There are ANNs called multilayer perceptrons that contain several hidden unit layers.

Analogs of such neural networks can be set up in the classroom by student teams in terms of the interactive teaching scenario (see below).

2.2.7. Egalitarian ("ape") paradigm. This paradigm is characteristic of some apes (chimpanzees and bonobos) and other monkeys (capuchins and muriquis). It is based on individual freedoms, respect for high-ranking members, and loose links among network members. It is characterized by mitigated hierarchies with tolerant high-ranking individuals that function in conformity with a set of social norms—the matrix—that restrict their power and secure the "rights" of all network nodes, including low-ranking individuals. The hierarchy is also mitigated by a system of decentralized horizontal interindividual interactions involving empathy and cooperation. These interactions manifest themselves in grooming, play, greeting rituals, food sharing, and postconflict reconciliation. Many egalitarian structures are multilevel systems; their large associations often include small-size loose fission–fusion groups (de Waal, 1996; Deryagina & Butovskaya, 2004).

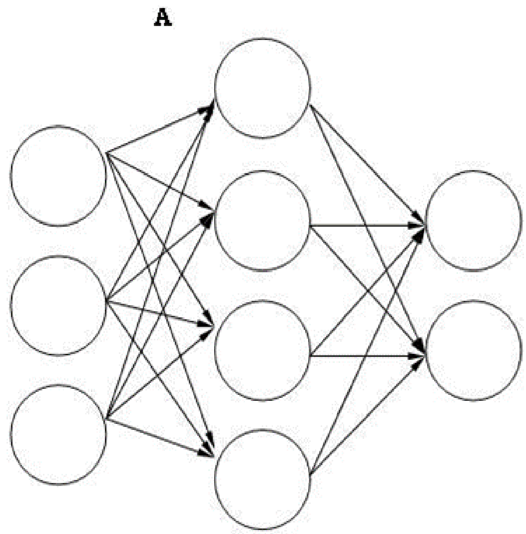

Figure 4. Neural networks combine consecutive (input → hidden layer(s) → output) and parallel information processing. (A) Perceptron; (B) Recurrent neural network with additional feedback links running from the output to the input layer.

The egalitarian ("ape") paradigm seems to be applicable to the organization of networked creative teams of enthusiastic scientists or scholars. This will be exemplified below by teams of software developers (The Agile Alliance; Cohn, 2010). The paradigm is also applicable to various kinds of networked labs emphasizing independent individual creativity and, nevertheless, the patronizing role of high-ranking network members.

Section three. NETWORK STRUCTURES IN THE SCIENTIFIC COMMUNITY: RESEARCH AND DEVELOPMENT. SCIENCE BUSINESS

3.1. Decentralized network structures as research teams. DNSs have proved to be sufficiently useful in the capacity of creative teams or science-based business firms. They seem to be of special interest to creative teams dealing with interdisciplinary issues. Because they are dynamic and light on their feet, DNSs should have considerable advantages over traditional "thick-skinned" hierarchical institutions, exemplified by an Academy of Sciences or a research institute, in new areas of research that still lack clear definitions (are in a state of flux) and whose practical usefulness is still to be tested.

An interdisciplinary research lab can be organized as a hirama (see above). Its main goal might be, for instance, developing inexpensive technology for producing biogas, a gaseous methane-containing biofuel, by fermenting agricultural waste products such as straw and dung. Similar to the hirama discussed in subsection 2.1, this network structure breaks the general goal down into subgoals including (i) screening for microbial cultures that efficiently produce biogas and typically represent multispecies associations; (ii) installing the necessary equipment such as bioreactors, methane tanks, etc.; and (iii) dealing with the economic aspects of the whole project, including the cost-benefit calculation. A special partial leader is assigned to each subgoal who merely stimulates the work of all hirama members on the respective subgoal and collects ideas generated by other network members. In compliance with the hirama principles, this network also has a psychological leader that promotes efficient work on all subgoals and helps other partial leaders; there is an external leader tasked with establishing contacts with other organizations.

A network was spontaneously established by a group of Russian microbiologists (Kirovskaya, 2005; Oleskin & Kirovskaya, 2006, 2007). During the second half of the 20th century, an informal association of enthusiasts took shape within the microbiological community in the Soviet Union. These enthusiastic microbiologists belonged to different formal institutions, e.g., Moscow State University, the Institute of Microbiology of the Academy of Sciences of the Soviet Union, the Institute of Epidemiology and Microbiology of the Academy of Medical Sciences of the Soviet Union, and others. They specialized in different fields of microbiology or other life sciences. However, all the scientists took an interest in the same subject, which can be denoted as "social microbiology". They were fascinated by the social life of microorganisms, the collective behavior of their cells, information exchange among them, and microbial populations as coherent, organism-like systems.

These shared goals and views enabled the adherents of this paradigm to established business relationships. Despite their different backgrounds and institutions, these enthusiasts held meetings and conferences, conducted joint research initiatives, and published their results. The independently working scientists V. V. Vysotsky, P. L. Zaslavkaya, A. V. Mashkova, O. I. Baulina, and others established an informal network in the mid-'80s when they all participated in a microbiological conference at the town of Ivanovo. It was during this conference that they found out that they held similar views on the microbial population as a system composed of diverse individuals—each of them making its own contribution to the well-being of the whole system. Like the microorganisms, the microbiologists decided to work together for the benefit of the whole network that was cemented by the new paradigm. For example, they produced the article titled "Polymorphism as a Developmental Trend in Populations of Prokaryotic Organisms" (Vysotsky et al., 1991). This spontaneous network structure in the Russian microbiological community, unlike a traditional hierarchical school of thought, was not founded by a single eminent scientist with the aid of his disciples. Instead, the network functioned as an invisible college: information was constantly exchanged between autonomous groups or individual scientists that were united by a common microbiological paradigm. The spontaneous network structure is depicted in Figure. 5

It is to be hoped that the history of this spontaneous network of enthusiastic microbiologists will be used to promote the establishment of a network structure dealing with a very important interdisciplinary topic that can be referred to as *Microbial Communication, Neurochemicals, and Probiotics* (see below for details).

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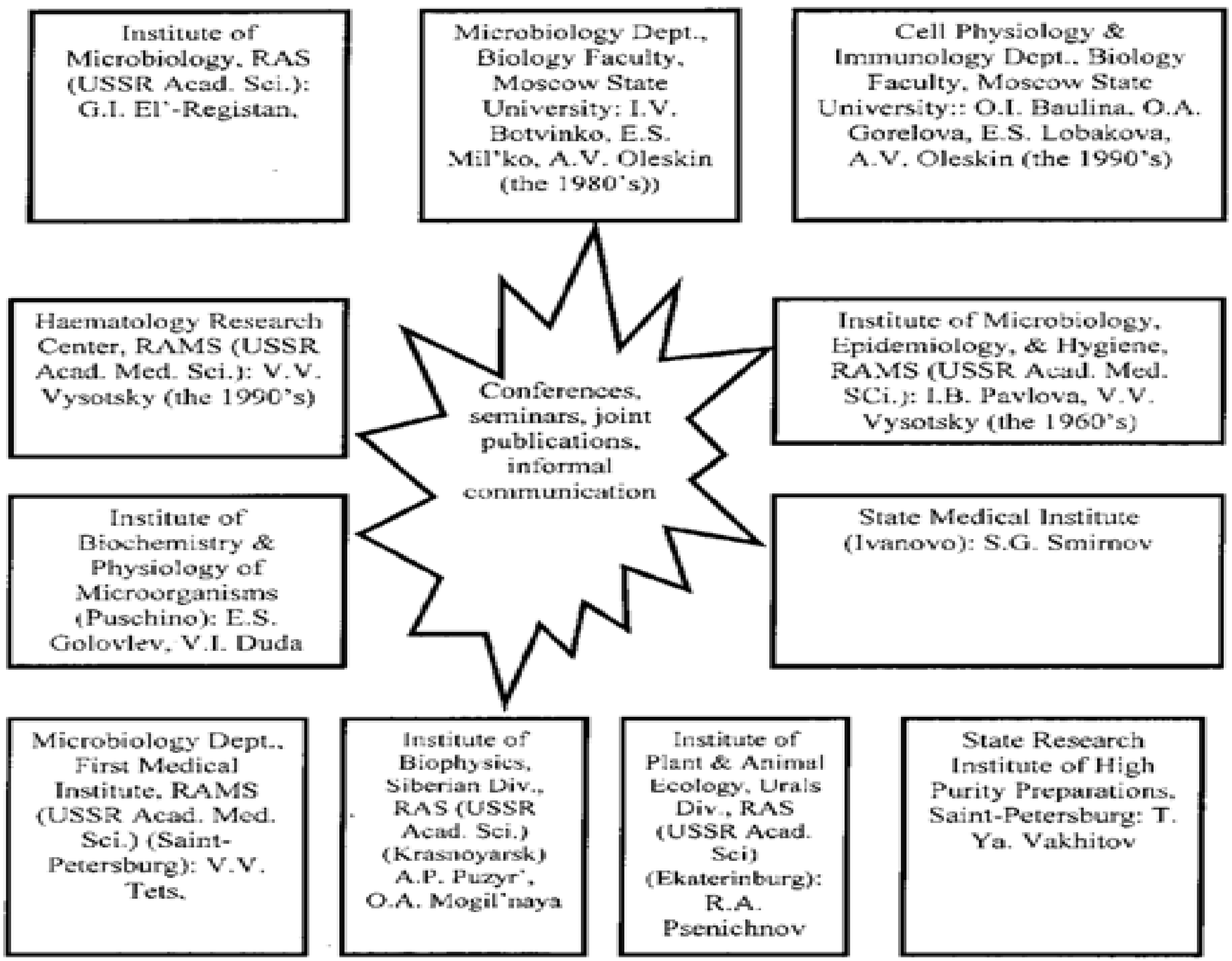
Figure 5. A spontaneous network structure within the Russian scientific community in the late 20th century (the 1960s–1990s). The network structure focused on the organization of microbial populations and on the communication between microbial cells. Based on the following works: (Kirovskaya, 2005; Oleskin & Kirovskaya, 2007). RAS, Russian Academy of Sciences; RAMS, Russian Academy of Medical Sciences. Note: 1. The period spent by a scientist at a particular institution is given in parentheses after the scientist's name; 2. Some institutions changed their names during the period in question; 3. Some scientists changed their position and affiliation during the same period



The decentralized organization of such research teams/labs considerably influences their creative work and its results. This influence can be summed up as follows (Kirovskaya, 2005; Oleskin, 2014a):

1. *They put forward important hypotheses related to areas far beyond the original scope of their research.* A large number of researchers in the field of the population organization and communication of microorganisms produced articles, theoretical papers, and monographs on general microbiological issues.
2. *Their scientific developments had significant philosophical implications.* Golovlev (1999) aptly called Academician Nikolay D. Yerusalimsky's theory "the philosophy of the microbial population".
3. Remarkably, *the network composed of microbiologists revealed structural similarities (isomorphism) to networks formed by microbial populations.* Like microorganisms with their functionally differentiated subclusters in decentralized biofilms, microbiologists with their different professional backgrounds and different, although overlapping, areas of research formed a heterogeneous network with a large number of "active centers".

4. *The network of enthusiastic microbiologists was capable of generating important scientific ideas that were "ahead of time"*: some of these ideas were similar to those put forward several decades later by the mainstream scientific community. The network was capable of visiting the future, of the *anticipatory reflection*[2] of the *future achievements* of the global microbiological community.

In this situation, the network structure-cementing matrix briefly discussed at the beginning of this work, functions as an "invisible boss" that orchestrates network members' activities. The whole network resembles a mystical entity (egregore) that does not only contain human individual and is endowed with its own supra-individual will. The matrix represents the "mental condensate" generated by human thoughts and emotions and having its own personality (Oleskin, 2016).

Modified *hirama* principles have actually been used by the network structure composed of software development teams that adopted the Manifesto for Agile Software Development on February 11–13, 2001, during a meeting at *The Lodge at Snowbird* ski resort in the Wasatch Mountains of Utah. According to their website (Beck et al., 2001), the conference involved representatives from Extreme Programming, SCRUM, DSDM, and a variety of other firms and organizations. It was emphasized that "a bigger gathering of organizational anarchists would be hard to find, so what emerged from this meeting was symbolic – a *Manifesto for Agile Software Development* signed by all participants". The new network was called *The Agile Alliance,* and it adopted a "set of values based on trust and respect for each other and promoting organizational models based on people, collaboration, and building the types of organizational communities in which we would want to work" (Ibid.). Software development was broken down into short stages (iterations) consecutively or concomitantly carried out by the network structure. Some of the 12 main principles set forth in the manifesto dealt with *The Agile Alliance'*s network organization. The interprofessional dialogue-promoting activities of *The Agile Alliance'*s are stressed in the principle that "business people and developers must work together daily throughout the project". In addition, the principle is adopted that "the most efficient and effective method of conveying information to and within a development team is face-to-face conversation". Therefore, such a development team looks like a primitive hunter–gatherer band engaging in collective hunting or waging war with their neighbors. Most *Agile* teams usually work in one room (the bullpen). The development team includes the client or his/her representative, as well as testers, designers, and managers (Cohn, 2010). The dynamic nature of the network organization, in contrast to the rigid character of bureaucracies, is stressed in the *Manifesto*, and it is assumed that "the best architectures, requirements, and designs emerge from self-organizing teams". Established over a decade ago, the network of software developers is currently increasing its influence, as evidenced by the fact that over 40 new signatories pledged their support to it during the February 15–28, 2014 period alone (http://agilemanifesto.org).

The question to raise regarding the biological paradigms discussed above is whether their analogs are applicable to the organization of research teams. Without equating humans and animals, it should be admitted that the network structures of enthusiastic researchers reveal some similarity to the egalitarian structures of apes (subection 2.7), at least in the following respects:

[2] The term *anticipatory reflection*, originally applied by Smirnov et al. (1982) to the lag phase, whose sub-stages foreshadow the subsequent phases of the development of a microbial population, can also be used with respect to the network structure composed of microbiologists.

1. *Respect for individual freedoms (particularly the freedom of choice) and rights.* The network of microbiologists discussed above respected the right of every individual or collective member to deal with his or her favorite area of research and to develop his or her own theories; this freedom was only limited by temporary obligations in terms of joint projects, publications, or conferences.
2. *Partial hierarchization of the structure associated with acknowledging the merits and degrees/titles of high-ranking network members* (analogs of high-ranking aging silverback males in gorilla groups); however, no network member can become the central leader and play the dominant role across the entire structure.
3. *Loose links between network members;* in an analogy to fission–fusion groups formed by, e.g., chimpanzees, individuals or subgroups can choose to either join the network or quit it.

Many traditional scientific institutions around the globe such as universities/colleges and academic institutes should indisputably remain hierarchical. They routinely perform a number of important functions: (1) they are responsible for maintaining the integrity of the scientific community and its main historical traditions as well as for creating its image at the local, national, and global levels; (2) hierarchies defend the interests of the scientific community in the face of various external and internal dangers ranging from attempts to seize the scientific community's property to the destructive views and attitudes of some young people who show disrespect for eminent scientists and contempt for scientific research unless it immediately results in gaining profit; and (3) the development of DNSs in the scientific community enables traditional hierarchies to fulfil a new function: in the capacity of experts, they are expected to determine the fate of these developing networks (including the selective sponsoring of some of the DNSs).

3.2. Decentralized network structures in terms of commercial R & D activities based on scientific research results. A challenging mission of the global scientific community is to efficiently apply its achievements to practical business projects dealing with IT, biotechnology, nanotechnology, pharmaceutics, space exploration, etc.

DNSs are expected to significantly contribute to such science-based R & D projects. In many countries around the globe, such projects are carried out by decentralized bodies exemplified by science parks at Oxford and Cambridge in the UK. They have little centralized control and, therefore, their operation largely depends on the goals and values shared by their members, i.e. the network's matrix as defined above. For instance, the decentralized Oxford Science Park is characterized by several important principles and distinctive features of its staff (Oxford Science Park, 2021). They are:

- Ambitious, for you and the Park's future
- Effective, providing you with the best environment to thrive
- Partnership-driven, working with you in the pursuit of excellence
- Professional, in everything they do
- Visionary, in planning for the future

It should also be re-emphasized that living nature has invented important organizational patterns that are potentially useful for human network structures. They include patterns combining decentralized networks and hierarchies that are exemplified by the eusocial structures of ants and other social insects (see subsection 2.5). Human analogs of ant worker teams with temporary leaders can be set up in science parks if the goal is to use scientific research results in business projects. In an analogy to ant worker teams with different "specialists" (foragers, scouts, queen retinue, etc.), such an R & D networked team could include members that concentrate on (i) basic research, (ii) its application to industrial projects, and (iii) the marketing of the products developed, respectively. Specialists of each kind can form temporary small-size hierarchical teams (5-8 members) which have temporary, situational leaders. These leaders get together and build up decentralized network structures engaging in discussions and debates that can involve leaders with the same or with different specializations, as well as relatively inactive generalists that, nonetheless, lend some additional weight to such network structures.

3.3. Networks in science-based business. Since business developments based on scientific research forms a part of the sphere of business in general, a brief rundown on how to use network structures in this sphere should be provided (see Oleskin, 2014a, b). Network structures including the aforementioned hirama model can be applied to SMEs that specialize in high-tech production (bio- and nanotechnologies, pharmaceutics, IT, etc.). For instance, a networked firm may deal with promoting digital platforms (to be discussed below). In compliance with the hirama model, the staff of such a networked enterprise can include partial leaders dealing with (i) digital economy-promoting social media; (ii) digital markets; and (iii) search engine optimization (SEO) using, e.g., Google Analytics. All network members constantly interact with these leaders. Without their support, the digital markets leader will hardly be able to orchestrate the operation of such markets. As a hirama-type structure, this network should also include a psychological and an external leader.

Apart from the hirama, science-based business can use alternative network structures that involve biological paradigms. Very small enterprises can make good use of completely flat networks that even lack partial leaders. A successful example was provided by 37 signals (Chicago) that specialized in software (Fried, 2011) and was structurally analogous to a fish school (subsection 2.4). The only difference from a typical homogeneous same-species fish school was that the staff included subgroups composed of different specialists, such as programmers and designers; in this respect, the firm was similar to a multispecies fish school including, e.g., jacks and barracudas (Pavlov & Kasumian, 2003). “37signals has always been a flat organization. In fact, flatness is one of our core values. We have eight programmers, but we don't have a chief technical officer. We have five designers, but no creative director”. To an extent, the 37 signals structure was hierarchical because there was a team leader, ”but that role rotates among the team every week. Each week, a new leader sketches out the agenda, writes up the notes about problems and performance, and steps up to handle any troubled customer interactions”. The flat network ideology that informed the structure of the 37 signals enterprise emphasized that “Moving ambitious people upward tends to lock down other capable people on the team” (Fried, 2011).

Network structures have so far been considered in this work at the social micro level, i.e. in the capacity of decentralized creative teams that can be used by SMEs. However, analogous structures can work at higher levels, including large firms and their alliances that can be designed as decentralized networks. For instance, Russian large-scale DNSs are typified by business clusters. These are locally concentrated groups of interacting enterprises. Joining together to form clusters usually increases production efficiency, minimizes the risks involved, and secures the competitiveness of the enterprises and of the whole cluster.

The resulting big DNS is actually a multilevel network of networks. Some of its *subnetworks*, i.e., the smaller DNSs that form a part of this *meganetwork* (the term will be revisited in Section 10 below), may be functionally specialized and represent collective analogs of the partial leaders of the hirama. However, some of the small DNSs may combine several different functions and, therefore, be similar to the aforementioned "generalists", i.e., those hirama members that do not function as partial leaders and are free to deal with several of the subproblems with which the hirama is concerned.

It may be expedient to supplement such a business cluster with a whole "psychological network", an analog of the hirama's psychological leader that, likewise, should help the cluster create a harmonious psychological climate. Importantly, each of the subnetworks should enjoy sufficient autonomy to establish its own contacts with external agents. For example, the subnetwork that combines several functions should be in a position to interact with any external organization outside the meganetwork. Moreover, each member of this multifunctional subnetwork should not be prevented from collaborating with any representatives of other firms and organizations.

Successful business DNSs that are partly similar to the hirama in organizational terms include

- *Teal companies* (Laloux, 2014) whose staff has no position titles or official job instructions; the responsibilities are redistributed among them whenever necessary. The three pillars of teal companies are the following principles: (i) *Self-management*, a system based on peer relationships with no need for hierarchy; (ii) *Wholeness* enabling employees to present their full personas, with which their impromptu job instructions should conform; and (iii) *Evolutionary Purpose*, the idea to let the organization naturally evolve; the company's mission develops together with the company itself. The formal head of a teal company only fulfills the function of representing the company while interacting with other companies, in an analogy to the external leader of the hirama.
- *Holacracy companies* (Robertson, 2015) based on decentralized management. Authority and decision-making is distributed through an ensemble (holarchy) of self-organizing teams in the absence of a management hierarchy. Like the hirama's partial leader who seeks the help of other hirama members as long as they deal with the subproblem within the leader's competence, role incumbents in the holacracy system enjoy exclusive rights in terms of decision-making as long as their specific roles are concerned. The hirama is analogous to one self-organizing *circle* in the holacracy system. The staff members within the circle are empowered to decide (during internal conferences) how their roles will be distributed. Apart from the flat network structure, the holacracy system also includes a hierarchical component. Circles are organized hierarchically, and each circle is tasked with a specific job by, and accountable to, a broader circle. Circles are linked by staff members performing the *lead link* and the *rep link* roles, which attend the conferences/meetings of both their circle and the broader circle to ensure alignment with the broader organization's mission and strategy.

Network structures in business, including the aforementioned teal and holacracy companies, can be functionally classified as follows:

- *Efficient (functional)* networks aimed at maximizing cost efficiency in the supply chain (Lee, 2002; Trkman & Desouza, 2012). A prerequisite for increased cost efficiency is information exchange among network members. For instance, if the supplier is familiar with the situation at the manufacturer firm level (and vice versa), this will prevent efficiency-decreasing problems such as stockout, as well as supplying goods in excess of the real consumer demand for them. Manufacturers can create supplier hubs[3] that enable them to easily monitor the situation at the supplier level. “For example, at their former manufacturing site in Fountain, Colorado, Apple Computer created a supplier hub that was operated by a third-party logistics company, Fritz Companies... The use of the hub has allowed the suppliers to have much better information about Apple’s needs and consumption patterns of the parts as well as about the inventory in transit” (Lee, 2002, pp.112-113).

- *Risk-hedging* networks. Such networks pool their members’ resources to share risks (Trkman & Desouza, 2012). In this respect, not only alliances between firms dealing with different production stages (they may be referred to as “vertical[4] alliances” in the literature), but also networks bringing together several firms concerned with the same stage (“horizontal alliances”), are of paramount importance. In a neural network-like fashion, the parallel functioning of several entities performing the same function, i.e., dealing with the same production stage, increases the reliability and resilience of the whole network structure. “A single entity in a supply chain can be vulnerable to supply disruption, but if there is more than one supply source or if alternative supply resources are available, then the risk of disruption would be reduced” (Lee, 2002, p.114).
- *Agile* networks aimed, according to Trkman & Desouza (2012), at “improving the ability of an organization in responding rapidly to changes in demand”. This is exemplified by Original Equipment Manufacturers (OEMs), companies specializing in producing parts, e.g., hoods, for the automotive industry in Europe. In terms of the more traditional hierarchical scenario—“in a centralized supply chain”—assembly tasks can be performed only by the OEM “who delivers the product to the dealers so that it can be sold to a customer” (Mourtzis et al., 2012, p.294). Forming a strategic alliance with suppliers and dealers makes the whole network more responsive to customers’ needs, particularly with respect to customizing production according to their individual preferences. For example, the customization of the hood (including its ornament) can be outsourced to suppliers
- *Innovative* networks “are problem sharing networks and comprise parties that exchange problems and solutions. An example of such a network is Procter and Gamble (P&G)’s Connect + Develop network. Instead of using formal alliances to find the best research and innovations, P&G now circulates problem stories throughout a network. The sources of innovation in the network are technology entrepreneurs around the world, suppliers and open networks (e.g., NineSigma, YourEncore, and Yet2.com). The problem stories are presented to these groups and anyone with an answer can respond” (Trkman & Desouza, 2012, p.8). Networks can make good use of network-level distributed intelligence; active work within the framework of a “collective neural network” is obviously promoted by collectivist attitudes and a sense of belonging.

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[3] The specific meaning of the term “hub” used by business people in this context is actually in conformity with its more general meaning with regard to *scale-free networks* where hubs are well-connected nodes having numerous links to other nodes, whereas the majority of nodes have relatively few links (Barabasi, 2002).

[4]Not to be confused with the other meanings of the words “vertical” and “horizontal” that are widely used in this work (vertical as hierarchical, and horizontal as non-hierarchical, respectively).

The different kinds of networks can actually be used in combination.

All the above functions can be efficiently performed by the following specific types of DNSs that can be applied to science-based business developments (Scherbakov, 2020):

3.3.1. Franchising and Brand Name Delegation. Interfirm network structures can result from optimizing production cost effectiveness. Resources necessary for initiating and maintaining the production processes are economized by a firm (the franchisor) that licenses the use of its brand and rights to sell its branded products and services to other firms (the franchisees).

3.3.2. Networked production patterns. Corporate firms make contracts with SMEs that they use for manufacturing accessories. These SMEs retain their legal autonomy. A SME specializing in a limited number of functions proves more efficient than a specialized corporate firm’s subdivision with its bureaucracy and transaction costs. In similar fashion, pharmaceutical networked companies can make good use of SMEs, each of them producing small amounts (milligrams) of drugs that nevertheless are sufficient to saturate the global pharma market.

3.3.3. Networked raw material purchasing («synergy of scale»). Several SMEs producing similar items form an alliance to purchase bulk amounts of raw materials at a lower price.

3.3.4. Using intermediaries and commercial agents: the producer company sets up a network of dealers that is legally independent of this company. This enables decreasing transaction costs and hedging risks with the aid of the intermediaries (that form decentralized networks).

In recent decades, these DNSs have been supplemented by some new types that are based on virtual networks.

3.3.5. Shared fixed asset use. Business parks or business incubators can minimize expenses associated with fixed assets by carrying out pilot projects for their client firms (see below).

3.3.6. Shared use of production means and work force. This is exemplified by crowd sourcing in which individuals or organizations obtain goods and services from a large group of participants on a voluntary basis with the aid of IT methods.

3.3.7. Raising funds for commercial projects. An example is provided by crowd funding strategies, when the support of a large number of sponsors is sought in order to finance start-up projects..

3.3.8. Selling/buying goods via digital platforms such as AliExpress or Amazon, which minimizes the transaction costs involved. Apart from supplying goods, digital platforms also help the participants hedge logistics risks (Scherbakov, 2020).

3.4. Network incubators. The DNS pattern can be used as a structural principle in *network incubators* that create favorable conditions for the maturation of new network structures in business. These DNSs are provided with the necessary infrastructure, software, telecommunications, customer and banking services; they may also get long-term credits and, in some cases, gratuitous financial support. Once the incubation period is over, most maturing networks will become self-sustainable [5]. Moreover, they will be tasked with financially supporting the incubators. For instance, hirama-type network structures dealing with various science-based R & D activities should supplement the list of their partial leaders with a commercial leader and an accountancy leader. This will facilitate the hiramas’ interaction with network incubators that can be set up by all those interested in the hiramas’ production, which might include know-how ideas or scientific concepts. Such interested---and sufficiently rich---customers may represent colleges or academic institutes, large companies, governmental institutions, etc. The fate of such maturing hiramas or other DNSs may be different.

[5] There are notable exceptions (see below).

Commercially oriented network structures are expected to be self-sustainable. However, DNSs that generate intellectual production may remain incubator support-dependent if their production, although not directly commercializable, is sufficiently important in scientific terms. Colleges or other prospective clients should invite experts to make decisions as to which of the DNSs are to be sponsored.

3.5. Networked expert teams. How can the aforementioned experts organize their work? It is not always possible to rely on the opinion of a single expert when determining a network structure's fate. Several interacting experts are more likely to adequately evaluate new DNSs. They may make consensus-based decisions. However, even without reaching a consensus, the very fact that each of them is aware of the existence of other experts (that may hold alternative views) might considerably influence their decision. A hierarchical structure with dominance-submission relationships among experts would probably impede their work. Therefore, it seems expedient to set up expert DNSs. They may include partial leaders dealing with specific areas of research or aspects of network structures and also generalists, i.e., experts that are sufficiently competent in more than one field of science. For instance, an expert DNS can evaluate proposals concerning the establishment of new networked labs specializing in biotechnology (which is an interdisciplinary field favoring network structure patterns). The partial leaders of the expert hirama-type network may concentrate on different evaluation criteria, including (i) scientific novelty; (ii) commercial feasibility; and (iii) practical importance of the applicant's biotech project.

Section four. NETWORK STRUCTURES CONCERNED WITH THE ENVIRONMENT

Scientific research, predominantly in the field of ecology, is on the agenda of many organizations that monitor and protect the environment. Actually, the imaginary hirama-type network discussed at the beginning of this work deals with an environmental task (*Monitoring the State of Plant Ecosystems*, see subsection 2.1 above). The Russia-based *Socio-Ecological Union (SEU)* whose members all have an equal status and shared environment-related goals is a decentralized body in accordance with its Statute. This is largely due to the SEU's historical roots. It took shape as a union of voluntary environmental teams (*druzhyny*) that spontaneously established a country-wide informal decentralized network. The Union that was officially founded in 1988, had no vertical administrative structure. Each SEU member is free to independently engage in environmental activities as long as they are in conformity with the Statute. "In order to organize a campaign, a flow of letters of support, or any other activity, members of the Socio-Ecological Union need NOT ask for permission from the leadership" (SEU Website, 2020). The Union includes a Center for Coordination and Information but this body exercises little centralized control over SEU activities. Instead, the Center is only concerned, according to the website, "with linking the activists of the ecological movement with experts specializing in different fields of science, with lawyers, with organizations which are responsible for preserving the environment, with journalists, with other public organizations in different parts of the world". (SEU Website, 2020).

Therefore, the Center and other SEU offices should not to be considered as the top of any hierarchy. Instead, they only represent network *hubs*, i.e., network nodes that are directly connected to a large number of other nodes and, accordingly, can efficiently interact with them. In terms of modern *network* science, the number of direct links between a given node and other nodes in the same network is called the *degree* of a node (vertex). Hubs are characterized by a particularly large number of direct connections, they are nodes “with unusually high degree” (Newman, 2012, p. 9), especially if this is a scale-free network with few well-connected nodes and a large number of nodes having very few direct links with other nodes (Barabasi, 2002).

The official documents of the Socio-Ecological Union emphasize that the most important capital accumulated by its members is the knowledge and experience constantly shared not only among these members but also with those who hold similar views and belong to other networks. It seems likely that the word *capital* as used in the above context is actually synonymous with the well-known sociological and psychological term *social capital*. Although a number of interpretations of this term has been presented in the literature, most scholars agree that social capital is based on “the value of connections” (Borgatti & Foster, 2003) that are related to trust, loyalty, and reciprocity (see Oleskin, 2014a, p.207). In Western Europe, the main goal of accumulating social capital in business networks often is to increase the competitiveness of all enterprises that join the networks. In the East (including Russia), the motivation behind social capital accumulation may be different: it predominantly involves personal (friendly) and also professional bonds and is often aimed at producing and/or protecting common goods. The environment forms a part of these common goods (Davydova et al., 2008). This interpretation of the social capital concept is illustrated by SEU activities as well as by the actions that were performed by its predecessors, the network structures of environmental activists in Russia (the *druzhyny*), and by other flat (nonhierarchical) environmental bodies exemplified by the Taiga Rescue Network or the Russian Bird Conservation Union.

In the preceding sections, attention was also paid to structures that combine horizontal and vertical patterns. Such combined structures play a major role in terms of environmental protection. A large number of nongovernmental network organizations, including those dealing with environmental issues, contain a hierarchical core substructure and a more loosely organized peripheral network (Davydova et al., 2008). The relative importance of the core and the peripheral network varies from organization to organization, and the typical scenarios are as follows:

- *The hierarchical core (e.g., containing the central body with the president) dominates the periphery.* This is characteristic of academic institutions dealing with the environment. A similar pattern is typical of environment-oriented (Green) political parties if their hierarchy aims to acquire political power. The *Russian Ecological Party* partly conforms with this pattern. However, it was originally established under the aegis of the predominantly networked *Russian Constructive Ecological Movement* also known as *Kedr* (the “Cedar”) and, therefore, should be considered in the next item in the list.
- *The core is less hierarchical (partly decentralized), and the peripheral network is as influential as the core.* This “dynamic equilibrium” situation is characteristic of a large number of international organizations including the Biopolitics International Organization and the International Eco-Ethics Union that is composed of interconnected networks called “local chapters”. The aforementioned Russian Ecological Party (REP) originally was just a small-size network that structurally resembled ape troops (see subsection 2.2.7 above) and included prominent Russian activists such as S. P. Zalygin, Full Member of the Russian Academy of Sciences (RAS); E. N. Belyaev, Principal State Sanitary Doctor; M. C. Zalikhanov, Full Member of the RAS; V. I. Danilov-Danilian, Environmental Protection & Natural Resources Minister of the Russian Federation; G. G. Onischenko, Deputy Chairperson of the Russian Committee for Health & Sanitary Supervision; B. I. Nikonov, Principal Sanitary Doctor of the Sverdlovsk Region; A. A. Panfilov, Chairperson of the

Cedar Movement; and V. I. Pokrovsky, President of the Russian Academy of Medical Sciences. According to the Russian Ecological Party's official regulations (see REP Website, 2020), its official headquarters place emphasis on interaction with the networked periphery and systematically makes efforts to promote and to bring together all constructive, environment-friendly social and political bodies in Russia under the auspices of REP. Once the initial small environmentalists' network finally became a full-scale party, it succeeded in establishing a number of nation-wide social organizations such as the Russian Ecological Independent Examination (REIE) body, the Green Planet Juvenile Movement, the Green Patrol Organization, and the Animal Protection Society (Fauna).

- *The network dominates the core; its hierarchy is only a smokescreen behind which the networks carry out their plans.* This scenario was described in the futuristic book *Netocracy…* (Bard & Söderqvist, 2002), which predicted the advent of a network society. The network's dominance over the hierarchy that merely legalizes the network's activities is characteristic of some environmental bodies including the long-lived (and currently active) *All-Russian Society for Nature Conservation* that was established in 1924 with the approval of the leaders of Narkompros (the Soviet-time People's Commisariat for Education), such as A.V. Lunacharsky, K. Krupskaya (Lenin's widow), and M. N. Pokrovsky. During the course of its long history, the Society included such eminent scientists as I. I. Akimushkin, P. P. Vtorov, A. M. Gilyarov, F. Y. Dzerzhinsky, N. N. Drozdov, L. A. Lisovenko, A. P. Khokhryakov, A. C. Severtsov, and A. V. Yablokov. An important achievement of the All-Russian Society for Nature Conservation was establishing a young enthusiasts' network (*yunnatsky kruzhok*) in 1955 under its auspices, with P.P. Smolin as a network-style partial leader, predominantly functioning as a mediator and educator. The same structural pattern applies to the World Wildlife Fund (WWF) including its Russian subdivision.

4.1. Achievements of environmental network structures in the example of the WWF. An important predecessor of the World Wildlife Foundation was the Conservation Foundation that was instituted in 1947 in New York by G. F. Osborn as an organization affiliated with the New York Zoological Society that is presently known as the Wildlife Conservation Society. The mission of protecting nature informed the original small loose network that included several eminent scientists and scholars. In organizational terms, this network was structured in conformity with the egalitarian ("ape") paradigm (see subsection 2.2.7). In 1990, the Wildlife Conservation Society merged with the WWF after becoming affiliated with it in 1985.

The World Wildlife Foundation was founded long before this point, in 1961. Prince Bernhard of Lippe-Biesterfeld was actively involved in establishing the WWF, and he became its first president. In 1970, he set up the WWF's financial endowment *The 1001: A Nature Trust.* An important part in promoting WWF was also played by Rockefeller who recruited the first staff members of the WWF, acting as a partial *organizational leader* at the initial stage of the life-cycle of the subsequently self-organizing network structure. This work does not aim to describe the history of WWF in detail and ignores some controversial points concerning this DCN, and only the WWF's Russian subdivision is to be briefly discussed.

The first WWF initiatives in Russia (still called the Soviet Union) were launched in 1988-1989. In 1994, a Russian representative office of the WWF was established. In 2004, WWF Russia was proclaimed a Russian national organization. Over the course of more than two decades, "more than 1 000 field projects aimed at preserving the nature of Russia were implemented. With the participation of the Foundation: more than 52 million hectares of unique territories have been granted conservation status, the bison and the Asiatic leopard have been returned to the wild, the Amur tiger and Far Eastern leopard populations have been restored, the snow leopard and argali in the Altai have been preserved, the "Bear Patrols" have been created in the Arctic, important changes have been made in the Criminal Code” (WWF Russia Website, 2020).

Using the example of the WWF, the features of decentralized network structures that facilitate their successful operation in terms of environmental conservation will be singled out here below.

1. The importance of ideas and values that unite the members of a network structure, i.e., of its matrix, should be re-emphasized. The establishment of the WWF was marked by adopting the WWF Morges Manifesto (1961), the founding document that sets out the fund's commitment to assisting worthy organizations struggling to save the world's wildlife: “They need above all money, to carry out mercy missions and to meet conservation emergencies by buying land where wildlife treasures are threatened, and in many other ways. Money, for example, to pay guardians of wildlife refuges .... Money for education and propaganda among those who would care and help if only they understood. Money to send out experts to danger spots and to train more local wardens and helpers in Africa and elsewhere. Money to maintain a sort of 'war room' at the international headquarters of conservation, showing where the danger spots are and making it possible to ensure that their needs are met before it is too late”. In the literature on network structures, it is stressed that the matrix of many networks includes important symbols that inspire network members instead of a hierarchical leader. This is the function that was obviously performed by the panda as the WWF symbol adopted in 1961. The real prototype, the giant panda named Chi Chi, had been transferred from Beijing Zoo to London Zoo in 1958 where it was seen by one of the cofounders of the initial “ape-style” network, Sir Peter Markham Scott, a British ornithologist and painter.

2. To reiterate, the decentralized pattern of a network structure facilitates a multi-aspect, generalized approach to its agenda, enabling it to take into account a wide spectrum of relevant issues. Of note is the *Pskov Model Forest* Project that was carried out by WWF Russia in 1999. In terms of this project, a new scenario of forest management was successfully developed, a highly efficient and profitable forestry business system was launched, and the natural habitats of forest animals and plants were conserved.

3. This integrated approach to the issues and problems on their agenda helps networks perform their mediator function: they aim to reach a compromise even if the parties involved originally seem to hold incompatible views (this will be referred to as the *conflict-mitigating mission* of DNSs below). This point is illustrated by a gathering in Assisi, Italy in 1986 to which the organization's International President Prince Philip, the Duke of Edinburgh, invited religious authorities representing Buddhism, Christianity, Hinduism, Islam, and Judaism. They all agreed that priority attention was to be paid to the environment. The generalizing trend characteristic of network structures facilitates their political mission: irrespective of the specific agenda, they all carry out the additional task of overcoming the barriers and boundaries that separate people on the planet. It seems likely that this barrier-overcoming capacity of DNSs helped the WWF launch its first seminal projects on the soil of the USSR during the *perestroika* period (1988-1989).

4. The same trend (in terms of brain neural networks, it can be compared to the spread of an original localized excitation area within the whole brain) enables the merging of network structures with the formation of *meganetworks,* or “networks of networks”. This provides the

subject of Section ten below. As for the history of the WWF, this trend manifested itself when the WWF Russia joined the international *Living Planet* network in 1997. Under the aegis of this international DNS, the Ergaki Nature Park was founded in the Krasnoyarsk Region in 2005; the Ukok Recreation Zone came into being in the Altai Republic in the same year. The eminent scholar Mark Granovetter (1973, 1985) emphasized, in his classical work, the "strength of weak ties" that connect people in social networks. The cumulative force of globally interconnected network structures was demonstrated during the *Hour of the Earth* global action in 2009.

5. Since many structures in human society are not based on network principles, it is imperative that DCNs should efficiently interact with non-network structures including the hierarchies of the political system and, with respect to the scientific community, the top rungs of the scientific bureaucracy including, e.g., the office of the President of the Academy of Sciences. The key role is to be played by partial leaders in the networks involved; they are expected to voice the collective decisions made by DNSs during negotiations with competent representatives of such hierarchies. "Leaders perform a large number of functions in this situation; they combine the roles of educators, mentors, and mediators that facilitate interactions involving power structures, business, the scientific community, the media, and rank-and-file activists" (Davydova & Usacheva, 2009, p.61). Successful interaction between the WWF Russia and political hierarchies is exemplified by a WWF-initiative-based strategy of Far East leopard protection that was adopted by the Russian state apparatus in 1998.

6. The important functions of DCNs include their capacity to efficiently "mobilize financial and human resources" (Davydova et al., 2008). A case in point: in response to the official decision to abolish the environment-promoting State Ecology Committee in Russia, the WWF and other relevant networks collected over 3 million signatures of those interested in carrying out a nation-wide referendum to re-establish the governmental office dealing with the environment. At a later stage, the WWF launched a campaign aimed at changing the Forest Law so as to cancel the alterations in the Forest Code that ignored the suggestions of environmentalists and ecologists (see WWF Russia, 2020).

7. Of relevance is the educational function of DCNs, i.e. their capacity "to update and instruct" the target audience (Davydova et al., 2008). This capacity manifested itself in the educational activities of the WWF in 2004. The main goal was to convince Russian citizens that the Kyoto Protocol (an international treaty which extends the 1992 United Nations Framework Convention on Climate Change) was to be urgently ratified. This campaign was successful, and the Kyoto Protocol was actually ratified by the State Parliament (Duma) of Russia.

8. Apart from educating and mobilizing people, networks can conduct scientific research, along with more hierarchical institutions. Networks encourage numerous enthusiasts to be involved in scientific studies. An example is provided by the campaign aimed at obtaining photographic documentation concerning the snow leopard in the Far East of Russia; trap cameras were installed thanks to the sponsorship of the WWF and other partner organizations, which enabled getting leopard images. In 2014, the efforts of the WWF together with the *Teplokom* Holding Company made it possible to measure the ecological footprint and evaluate the environmental status of some Russian regions (WWF Russia, 2020).

It follows from all the above that the history of the WWF, especially on the Russian soil, demonstrates the potential advantages of DCNs in terms of their educational, inspirational, and scientific research-promoting functions. However, performing these functions necessitates an efficient dialogue between decentralized networks and other types of social structures, including centralized hierarchies. This dialogue is promoted by mediators that will be referred to as *social chaperones* below.

4.2. Decentralized network structures in action: applying various paradigms to plant resource protection. A hirama dealing with plant resources was considered by us at the beginning of the present work. This subsection includes some of the results of a master-level project carried out by Cao Boyang, an MSU-BIT University student (Shenzhen, China), under my supervision. It demonstrates the applicability of biological paradigms of network organization to the challenging mission of flora conservation.

4.2.1. Applying the cellular paradigm to plant resource protection. The cellular network paradigm, like several other paradigms originally "invented" by biological evolution, can find application in human network structures set up for various purposes, including, notably, environmental protection. As mentioned above, this paradigm is used by the colonies and biofilms of unicellular organisms. Its analog in human society is a network characterized by a tendency towards the formation of collective "superintelligence" from the individual minds of network members on the basis of a set of unifying explicit and implicit ideas and behavioral norms – of the intellectual matrix that underlies the network, in an analogy to the material extracellular substance in which microbial cells are embedded in a colony/biofilm. The application of the cellular paradigm to human network structures holds special value because it enables creating innovative teams that can brainstorm a challenging issue (See also Section 8).

As far as the environment including flora is concerned, the goal should be developing novel strategies of "green business" also known as bio-business. Its pivotal concept is that the success of a business should be evaluated, apart from the profit, also using criteria related to environmental protection. They boil down to the following main points (Vlavianos-Arvanitis & Oleskin, 1992; Vlavianos-Arvanitis, 2003):

- Environment-protecting regulations that are compulsory for all business enterprises and prevent environmental pollution;
- Tax policies that favor enterprises which make efforts to keep the environment clean and sanction those using environment-endangering raw materials or equipment;
- Biological education that familiarizes people with practical bio-business strategies

How should these measures be applied to businesses that, e.g., rely on petrochemicals as raw materials and pose the threat of polluting the environment with toxic products?

This is a situation that really calls for the collective creative work of a cellular paradigm-implementing team of enthusiasts. "Personality merging" during brain-storming sessions and role-playing games should result in producing specific detailed instructions for "green" business people and the officials that supervise their activities.

4.2.2. Potential application of the modular paradigm to environmental protection. In contrast to the cellular paradigm (see above), the modular paradigm implies that the individuality of each network element (module) is retained to a much greater extent, even though all the modules are connected by a single stalk (coenosarc), which is analogous to the common ideology that unites all network members in human society. Network elements can compete, and not only cooperate, with one another. Different network members have different individual work rhythms,and, therefore, competition promotes successful work at the level of the whole network thanks to the effect discussed above with reference to colonial cnidarians (Section 2): a single network member's impact is potentiated if its behavior is in unison with that of a majority of other members in the modular network structure. "An analogous phenomenon is network-facilitated leverage. Each member who contributes some resources to the network may obtain access to a much larger pool of resources belonging to the whole network. Network-facilitated leverage can deal with material goods, information, social status, or communication facilities, depending on the types of resources that are collectively used by the network" (Oleskin, 2014a, p.213; see also Chuchkevich, 1999).

What are the prospects for using the modular paradigm in terms of environmental protection? A prerequisite for environment-protecting activities is biological education that is an essential part of the training program for new environmental enthusiasts.

In the modern-day world, humans are constantly confronted with biology-related issues and problems. The syllabi at all education levels should, therefore, be supplemented with knowledge concerning living nature and related ethical values It is imperative that the students, regardless of their profession, should acquire sufficient knowledge concerning life and related ethical values. This means that the students, apart from possessing basic biological knowledge, should also assume a protective attitude towards life and the sense of responsibility for it. They should realize that they should stop doing harm to living nature because this is immoral, and not only because such behavior towards living nature endangers the life of humankind itself. Importantly, the students should be able to appreciate the beauty of the manifold of life as exemplified by a flower, a coral, or a bilayer lipid membrane. It is imperative that teaching biology should provide new foundations for the whole educational system (Oleskin, 2014a, 2016).

An urgent task is to make good use of network paradigms in order to develop social techniques of interactive teaching based on decentralized networks of students. A prerequisite for such techniques is the students' active creative work and ongoing communication among them and between the students and the teacher as well as the use of psychological methods of stimulating the students' work. Students should set up classroom network teams that do the creative tasks given by the teacher.

There are important reasons, in many situations, for choosing the modular network paradigm as the optimum organizational pattern of classroom creative teams. Each of such teams is to be considered a semi-autonomous module within the framework of a higher-order network that includes all students in the classroom. Like zooids, such modules are expected to solve problems in parallel, to compete with one another (which should increase their motivation) and nonetheless, to cooperate in terms of carrying out the same project, e.g., suggesting new legal and (bio)political regulations for the purpose of protecting the forest around Shenzhen (China) or another big city. Each of the teams (modules) acquires new knowledge and skills while doing creative tasks in the classroom; each of them also acquires its special team image and collective identity. However, all the modules are interconnected because they all deal with the same project that represents an immaterial analog of the coenosarc holding zooids together in a cnidarian colony.

4.2.3. Potential application of the rhizome paradigm to environmental protection. This paradigm incorporates several principles that are of considerable social importance. First, each filament (hypha) in a fungal mycelium is a linear structure. Each of its parts (each cell in septate hypha) only interacts with two adjacent parts (cells). As mentioned above, neighboring hyphae can branch, and their side branches can merge at some points. Another socially relevant feature of many rhizome-type networks is their capacity to exist as a mycelium and as a group of separate yeast-like cells and to interconvert between the two forms. A network's work on a multi-stage project can involve repeated interconversion between (i) the independent functioning of each network member (or each small subnetwork) which necessarily results in competition among them and (ii) the operation of a close-knit team in which cooperation dominates over competition. Such a multi-stage project can, for instance, pursue the important goal of *Replacing Petrochemicals with Environment-Friendly Bio-Fuel* (such as yeast-produced ethanol, bacterially synthesized butanol, and lignocelluloses made from wood). Introducing each of these bio-fuels could constitute a self-contained stage within the whole project to be carried out by a rhizome-type networked organization.

4.2.4. Potential application of the equipotential paradigm to environmental protection. The tendency toward minimizing individual differences and equalizing social ranks that is characteristic of an equipotential, leaderless fish school should find application in network structures in human society; this paradigm can be used, for example, in SMES (see subsection 2.2.4).

The present work concentrates on stimulating the efficiency of decentralized networks, and this subsection focuses on the potential application of the equipotential paradigm in terms of environmental protection. Such networks tend to be leaderless, they lack even specialized partial leaders that are characteristic of other network types. The project carried out by such a network is not broken down into subprojects. All network members work in parallel on the same project, stage by stage (see the discussion concerning the 37 signals firm in Subsection 3.3 above). To reiterate, the parallel functioning of many network nodes enhances the network's robustness and reliability in the face of stress factors. In addition, the collaboration of many nodes synergistically increases the intellectual power of the whole collective "information processer", comparable to a distributed system of computers.

Importantly, flat leaderless structures that reveal much similarity to fish schools in organizational terms, have been already established in the field of environmental conservation. Such organizational principles---and the important role of informal interactions among network members---are stipulated in the official documents of the Socio-Ecological Union (SEU) discussed in some detail above.

4.2.5. Potential application of the eusocial paradigm to environmental protection. Networks following this pattern include a few temporary hierarchical teams with "team leaders" that nonhierarchically interact to form a flat higher-order network (see subsection 2.2.5). Another feature of many eusocial structures of insects that can be creatively used in human society is that specialized worker teams with their leaders co-exist with a pool of non-specialized network members; they are potentially ready to make their contribution to any kind of job. It is to be hoped that efficient measures for protecting the environment of any region of the planet will be promoted by setting up small temporary hierarchical teams (with team leaders) that will be embedded in the matrix of a higher-order horizontal network. This meganetwork is expected to have the potential to carry out large-scale projects that require costly equipment for assessing such environmental characteristics as the pollutant concentration, the radioactivity background level, or the intensity of plant photosynthesis and respiration.

The application of network paradigms to environmental protection is considered in the Table.

Table. Network paradigms in biological systems and their application to human society as exemplified by network structures dealing with environmental protection Note: the Table includes the *egalitarian paradigm* that is not discussed in this section but is also applicable to DNSs.

Paradigm	**Implementation in biological systems**	**Typical examples**	**Implementation in human society in terms of environmental conservation**
Cellular	Behavior coordination depends on cell–cell contacts and distant communicative signals. The system is consolidated by the matrix, an extracellular biopolymer structure	Colonies/ biofilms of microorganisms, cell cultures	A biofilm analog is a structure made up of human individuals that are cemented by ideas, myths, and spiritual values. The structure can develop guidelines for green business activities
Modular	The paradigm is characteristic of biological systems that contain many uniform units (modules); the predominant organizational pattern is flat (leaderless)	Colonial cnidarians, bryozoans, and ascidians	Creativity-promoting stress is caused by the tension between competition among nodes and cooperation in terms of the network's project, e.g. a classroom task given to a student team

Rhizome-type	Nodes and links cannot be distinguished. The network consists of filaments (hyphae, rhizoids, roots) as uniform elements: the network can interconvert between a system of filaments and a group of separate cells	Mycelial fungi, plant rhizomes (rootstock)	The paradigm can inspire social engineers that create dynamic network alliances with changeable structures that do multi-stage tasks (e.g., assess the ecological effects of constructing a new road)
Equi-potential	In the absence of a leader, a chance individual temporarily occupies the foremost position in the network structure. Individual differences among nodes in one network are minimized	Many fish species, cephalopodes ,	Such completely flat networks are exemplified by “smart crowds”, small-size creative teams, and environmental bodies such as the Socio-Ecological Union
Eusocial	Teams of active specialists with situational leaders form a part of a flat higher-order structure. Such active teams interact with a pool of mobilizable generalists	Ants, termites, bees, naked mole rats	Working teams with temporary leaders interact with non-specialized network members within higher-order networks, e.g., small environmental teams that combine to deal with large-scale projects
Neural	Neural networks are capable of collective information processing and decision-making. “…Neural networks can create the image of the whole object based on its fragments” (Oleskin, 2014)	Animal or human nervous systems and their analogs	Working teams with temporary leaders interact with non-specialized network members. They can find application in environmental education
Egalitarian	Based on individual freedoms; respect for high-ranking members; and *loose* links between network members	Chimpanzees bonobos, capuchins, muriquis	The paradigm is applicable to networked labs emphasizing independent individual creativity and the patronizing role of high-ranking network members

Section five. NETWORK STRUCTURES IN HEALTH CARE

Decentralized network structures have much potential in terms of health care. A real-life example is the AntEra Association that has recently been founded by A.A. Krel’ (AntEra, 2019). It is aimed at treating people suffering from rheumatism in Russia. Apart from health care workers, the network structure includes patients and their relatives. The founder of the Association emphasized the importance of the “formation of a Community of people with chronic health problems, their relatives, and experts interested in helping those in need of medical treatment. Such assistance should not be confined to medical treatment only. It should deal with all spheres of the patients’ life, including social, economic, cultural, psychological, and spiritual aspects”.

Decentralized cooperative network structures can be established at two different organizational levels:

- At the level of a network alliance that comprises several teams or, in the realm of business, several enterprises. A.V. Bobrovsky (2010) pointed out that network organization can be used for promoting both “intraorganizational collaboration” and interactivity “among companies and company groups”. In Russia, successfully operating networks in the field of health care include the Medicine Joint-Stock Company, the European Medical Center, the MedSi Company, and Scandinavia; undoubtedly, similar real-life examples of flourishing networked health care centers can be provided by other countries. Organizationally, networks can be formed by several teams of similar size or around one relatively big “core team”; in the latter case, the network is from the very beginning prone to become a hierarchy dominated by the larger team.

- At the level of a separate team; such a team lacks a boss because its decentralized structure includes several partial leaders (see subsection 2.1 on the hirama above).

For instance, a hirama-type network can represent a creative lab dealing with such an interdisciplinary and multi-aspect topic as *Treating and Rehabilitating COVID-Infected Patients*. The project is subdivided into several subprojects. For example, the above project can be broken down into:

a. *Virological Subproject:* Investigating the pathogenic virus and the pathogenesis of the COVID-19 infection
b. *Restorative Medicine-Related Subproject:* Actualizing the functional reserves of the human organism in order to ameliorate the health state of infected people and to improve their quality of life,
c. *Spiritual Subproject:* Using the inspirational potential of the network for reassuring coronavirus-infected people and promoting their feeling of belonging to the network and the conviction that their life is sufficiently useful for the whole society.

It was pointed out in Section four on environmental DNSs that a network structure tends to accumulate *social capital* associated with a special psychological atmosphere that promotes trust, loyalty, and readiness to attain the network’s goals and to obey its behavioral norms. The enthusiasts that have joined the decentralized hirama-type network considered above may be altruistic volunteers that are ready to work for free or they may expect an adequate reward for their efforts. However, an important trend in the development of most networks is that pragmatic incentives are gradually replaced by altruistic motivations associated with the network’s ideological matrix.

In compliance with DNS principles, specialized partial leaders constantly interact with nonspecialized network members (the *generalists* – not necessarily in the medical meaning). The pattern based on a combination of a pool of specialists and a number of generalists that can be used by the specialists whenever necessary is relatively widely spread both in human society and in biological systems exemplified by insect societies following the eusocial paradigm (subsection 2.2.5). Of some relevance to the behavior of people involved in DCNs, including those specializing in health care, is a recent study with ants in which the researchers limited the amount of available food by removing some of the honey dew-supplying aphids. The ants responded by mobilizing a part of usually inactive individuals that became “specialists belonging to small teams that took care of <the few remaining --inserted by O.A.> aphid colonies” (Novgorodova, 2003, p.229)

DNSs promote non-bureaucratic scenarios of medical treatment and rehabilitation, and this point was illustrated above by an imaginary network dealing with COVID patients and the real-life network called AntEra. Another aspect of the potential role of DNSs is associated with their involvement in training health care specialists within the framework of DNSs’ educational mission (see Section 6 below).

5.1. Hypothetical pilot network structure in the field of medical microbiology. The implementation of various paradigms of network structures can be illustrated in the example of an imaginary network that would bring together scientists and health care specialists and focus on *Microbial Communication, Neurochemicals, and Probiotics*. This network structure could be of direct relevance to restorative medicine. Its importance is primarily due to the fact that microorganisms, including useful probiotics, produce a wide spectrum of neuroactive substances that influence the human brain (reviewed, Oleskin & Shenderov, 2020). This beneficial influence is of significant medical and psychological importance. The interdisciplinary field is not on the agenda of any bureaucratic research institute. Such institutes only deal with some of the facets of the issue separately.

A pilot network structure for carrying out the aforementioned project comprises three modules that are concerned with the following subprojects.

Module 1: *Social Organization and Communication of Microorganisms*

Module 2: *Impact of Microbial Products on the Brain*

Module 3: *Probiotics*

This network structure is to combine two different models of DCNs: (i) the neural network (see Section 2, subsection 2.2.6); and (ii) the multiple-order hirama.

Each module also combines the neural-network and the hirama pattern. This is exemplified by Module 1. (*Social Organization and Communication of Microorganisms*). According to the neural-network scenario, all members of this module of the network form three distinct layers:

- The input layer: analysis of the literature data and of their own relevant findings
- The hidden layer: generalization of the information obtained and preparation of the draft versions of the results of expert analysis (e.g., regarding the efficiency of treating patients with probiotics)
- The output layer (comprising relatively few members): making the final decision on the basis of the reports of the hidden layer members and distributing it to medical institutions and other kinds of clients.

The members of the input and hidden layers work as generalists because they deal with all subprojects of Module 1. However, the members of the output layer are specialized hirama leaders; they are concerned with the following subprojects:

Creative partial leader 1: *Microbial Social Organization;*

Creative partial leader 2: *Microbial Communication*.

Creative partial leader 3: *Using the Data Collected by Leaders 1 and 2 in Restorative Medicine*

In compliance with the principles of the hirama, these leaders obtain data from all hidden layer members that form a single pool. Each of the leaders provide the input and the hidden layers with the feedback that can used for error correction (the principle of Hopfield recurrent networks, cf. Figure 4, B in subsection 2.2.6). As a hirama, Module 1 also includes (i) a psychological leader and (ii) an external leader. It is the external leader who reports the final results that combine the data documented by the three creative leaders. This final report is presented during the meeting of the external leaders of all the Modules; their combination represents a second-order hirama.

In similar fashion. Module 2 and Module 3 are internally structured as neural networks (with input, hidden, and output layers) and, nevertheless, also represent hiramas because their output layers consist of specialized creative leaders; each of these Modules also has a psychological and an external leader. The external leaders conduct regular meetings, in order to form a higher-order hirama.In this hirama, they represent not external leaders, but creative partial leaders. Their projects represent subprojects within the framework of the more general project of the second-order hirama. As mentioned above, this general project is concerned with *Microbial Communication, Neurochemicals, and Probiotics*.

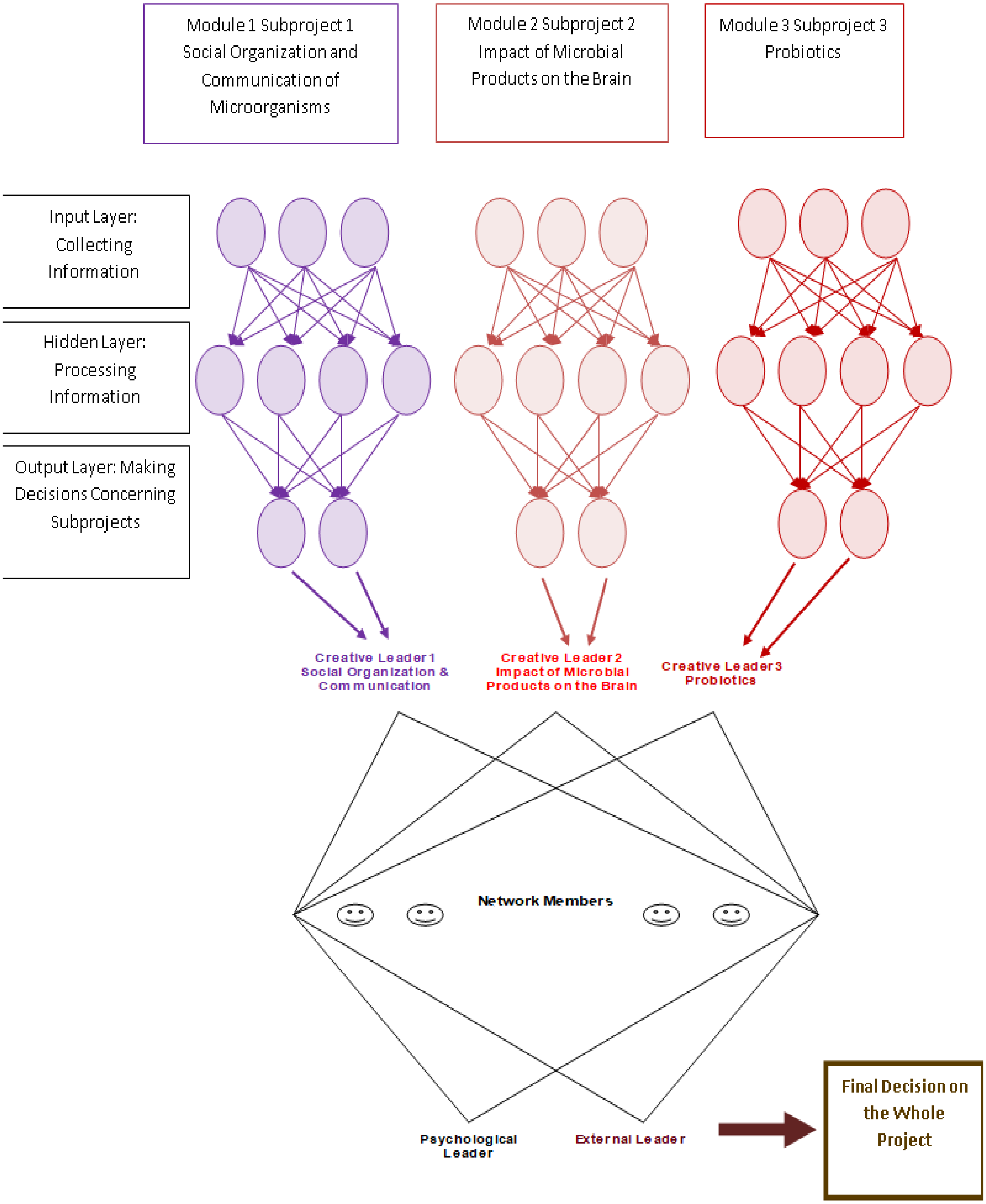

Figure 6. A pilot multiorder network structure for a creative decentralized team specializing in *Microbial Communication, Neurochemicals, and Probiotics*

The second-order hirama (a hirama of hiramas) should also have a psychological leader and an external leader. The external leader is to report the results of the work of the whole structure to the clients that might range from the Russian government to medical and scientific institutions and to the people at large; the same leader is responsible for contacts with other networks as well as other kinds of structures such as hierarchies and (quasi-)markets with which the second-order hirama has to interact. The second-order hirama may include additional members. They are generalists that are not dirrectly involved in any of the Modules; nevertheless, they can express their opinions on the whole project. The structure of this multiple-order decentralized network is represented in Figure 6.

5.2. Network structures in terms of restorative medicine. As mentioned above, decentralized network structures are likely to promote a philosophical worldview and encourage an integrated approach to any theoretical or practical issue, DNSs are expected to have special potential in terms of *restorative medicine*..

Restorative medicine, a modern interdisciplinary subfield of medicine, comprises the whole system of research and practical activities aimed at actualizing the functional reserves of the human organism, promoting the health of people, improving their quality of life, and overcoming problems caused by harmful environmental factors, a disease, or a physical/psychological trauma. Restorative medicine deals with patients during recuperation or remission periods; special emphasis is usually placed upon non-surgical and drug-free treatment strategies. The main professed aims of restorative medicine also include the prevention or amelioration of disabilities or at least an improvement of the life quality of the disabled. A prerequisite for attaining the aforementioned aims is setting up a goal-oriented medical care system. Restorative medicine "balances and optimizes overall body chemistry using bioidentical hormones, vitamins, minerals, herbal extracts, probiotics, 'superfoods', etc. It is a natural way of returning your physiology to its proper state so that your body can heal itself" (Smith, 2015).

Beyond any doubt, a DNS such as a networked team composed of enthusiastic rehabilitation therapists in combination with specialists ranging from cardiologists to psychotherapists could facilitate this innovative health care strategy; it would also promote a feeling of belonging in patients as they should also form a part of such a decentralized network. This would increase self-esteem and psychosomatically accelerate the rehabilitation process.

Section six. NETWORK STRUCTURES AND EDUCATION

6.1. Network structures in terms of interactive teaching. It is hardly possible to improve the efficiency of scientific research institutions (including those dealing with science-based commercial R & D) without reforming the educational system in order to improve the training of future researchers. A significant contribution to the modernization of the educational system can be made by decentralized network structures.

Network structures composed of students in the classroom[6], i.e., decentralized project teams with split leadership, have successfully been used in terms of interactive teaching by a number of innovative teachers including, e.g., the Russian educationalists Dmitriy Kavtaradze (1997, 1998), Alexander Kamnev (1997), and Ludmila Pivovarova (Oleskin et al., 2001; Pivovarova et al., 2002). Interactive teaching implies that there is interactive learning: apart from attending lectures

[6] Apart from their creative potential in the classroom, network structures made up of active students are also quite efficient in terms of *outdoor* classes.

and completing classroom tests, students are involved in collective work on creative tasks (Angelo & Cross, 1993; Silberman, 1996; Kavtaradze, 1997, 1998; Morrison-Shetlar & Marwitz, 2001; Watkins, 2005).[7] For example, during geography classes, students are to compare two different parts of Northern China in terms of landscape, flora, and natural resources, with the help of the online materials they locate on the Internet. Several subgroups in the classroom report the results obtained by them. The results can be compared and evaluated. All students participate in making group-level decisions, and they take responsibility for the results of the collective work; they should appreciate its meaning and be able to reflect on it.

Student teams can make good use of various interactive teaching techniques ranging from brain-storming sessions to role-playing games in which, one of the students acts the role of the director of a soap factory while another is the head of a commission tasked with monitoring the environmental pollution that is caused by this soap factory.

"Instead of just giving the information to the students, teachers encourage them to come up with ideas on how it connects to their own world, thus constructing their own meaning of the material" (Pulsifer, 2013). An important factor is a supportive and friendly climate that enables the students—apart from acquiring new knowledge—to improve their cognitive capacity and to develop advanced forms of interindividual cooperation that currently involves using virtual communication facilities and online information.

Interactive teaching is facilitated by the formation of student teams whose goals are set by the teacher. This pedagogical approach is referred to as project-based learning (PBL); it was originally suggested a century ago by Kilpatrick (1918). PBL is "a highly effective means of motivating students to learn independently" (Chang & Lee, 2010, p.961). Teams use a variety of interactive learning techniques ranging from brainstorming to role-playing games.

By fostering creativity, students' networks produce a number of other beneficial effects: they make classroom work more diversified; give students more freedom in terms of planning their activities (Chan, 2013); increase students' confidence and resilience; enhance their motivation and engagement; help them develop proper social, emotional, and thinking skills; and improve school attendance (Davies et al., 2013). Importantly, the tendency towards setting up task-oriented network teams in the classroom often comes into conflict with the hierarchical environment characteristic of performativity culture that is widespread, for example, in the United Kingdom (McLellan & Nicholl, 2013). This culture is characterized by accountability mechanisms that are largely based upon standardized tests of students' performance and academic achievement.

In terms of interactive teaching/learning, the teacher plays the unusual role of a network hub whose functions include facilitating the network's operation by consulting the students, providing general guidelines in terms of the tasks involved, and supplying the necessary materials. The teacher tends to be 'less prescriptive' in lesson planning (Davies et al., 2013), allowing more room for student initiatives and self-organization, both in terms of group structure and the group's overall agenda.

The teacher's role is even less hierarchical if the team-teaching scenario is used. "Team teaching involves two or more teachers sharing teaching expertise in the classroom and engaging

[7] Actually, even lecturing can become at least partially interactive if the lecturer uses student feedback-promoting techniques, e.g., demonstrates a picture and lets the students discuss it, asks a question, waits in silence for about 30 seconds, and encourages the audience to give a short answer to the lecturer's question. Such techniques enable some students to play the roles of temporary partial leaders and to mitigate the teacher–student hierarchy.

in reflective dialogue with each other" (Chang & Lee, 2010), as exemplified by the collaboration of a computer teacher and an English or a geography teacher in a school in Taiwan. Teachers form a subnetwork (cluster) within the fractally-structured, higher-order network established in the classroom in terms of a project-based interactive teaching scenario. The teachers give the students several different perspectives on the subject, but the problem is that a conflict between these perspectives can potentially arise; special measures are to be taken to cope with this type of conflict. A hirama-type strategy can be used to assign the role of the conflict-mitigating mediator (psychological partial leader) to an additional teacher.

Despite all efforts to create completely decentralized network structures, classroom student teams are moderately hierarchized. Not only are the teacher–student relationships necessarily hierarchical (although they form a mitigated hierarchy), students themselves have different social ranks, and some of them tend to become informal leaders. As a participant in a classroom group discussion noted, "as often happens in groups, one member decided to take over meeting times, delegation of responsibilities, and actions" (Neuman et al., 2009). In cross-age groups, older students "were seen positioning themselves as both teacher and researcher for younger children" (Dillon et al, 2007, quoted according to: Davies et al., 2013, p.86).

Hierarchical relationships in student groups (teams, workshops) in project-based interactive teaching can be limited by egalitarian social norms introduced during such classes. This concerns also teacher–student interactions because interactive teaching is facilitated by allowing students to "initiate their own activities or make their own choices within a loosely framed activity" (Davies et al., 2013), i.e., by respecting their individual freedom and rights, regardless of formal and informal rank and status.

If hirama-type network teams are set up during interactive classes, students feel free to join and quit each of the several temporary creative subnetworks (subgroups) centered around each partial leader during the collective work on a classroom project. This is similar to the fission–fusion pattern that is typical of chimpanzee troops, as well as of many hunter–gatherer bands, with temporary leaders. The creative work of a team of students is stimulated during an interactive teaching session if the students face sufficiently important challenges, and if teamwork and a sense of belonging are promoted.

6.2. Applying DNSs to interactive teaching strategies: case studies. The role of network structures in terms of interactive teaching is illustrated in this subsection in the example of classes on *Environmental Pollution in a City.* The teacher explains the scenario of a role-playing game: "You live in a city with a high environmental pollution level. I'm showing you data on the concentrations of manganese, cadmium, and lead in the atmosphere. This map also shows the location of environment-polluting factories. Your task is *to suggest ideas enabling us to prevent an environmental catastrophy".* In a *hirama*-like fashion, the task is broken down into subproblems such as (1) *Making Technological Changes in the Factories in order to Improve the Environmental Situation;* (2) *Creating Economic Incentives for Stimulating Environment-Friendly Production Scenarios;* And (3) *Restructuring the Administrative System in order to Facilitate its Direct Interaction with Local Industrial Agents and Environmental Activists.* A partial creative leader can be assigned to each of the subproblems. There are a large number of alternative ways to subdivide the overall task, and the students can make their choice themselves, with the teacher playing the role of both a facilitator and an adviser.

A network (sensu stricto) can be a structure of choice with respect to student teams that are established during these interactive classes. However, such teams can also use the hierarchical (bureaucratic) organizational pattern; both patterns have their pros and cons.

The potential advantages and disadvantages of network structures in the classroom were revealed during a series of interactive classes that were conducted at a high school (school No.119, Moscow) on the subject of *City Environment and Neurochemistry* (Oleskin et al., 2001). The classes focused upon the effects of pollutants, e.g., heavy metals, on the human brain. They are known to disrupt the functioning of neurochemicals, i.e., substances involved in transmitting impulses from neuron to neuron in the brain's neuronal networks. For example, the metals lead, manganese, and cadmium decrease the activity of serotonin-dependent (serotonergic) networks, resulting in depression, anxiety, and increased aggressiveness, which may cause criminal behavior (see Masters, 1994, 2001).

The group of about 30 students (aged 15–16 years) was given a short lecture on the subject. It was followed by several creative tasks completed by temporary subgroups (teams), which included:

1. Assessing the environmental situation in several districts of Moscow using the following characteristics: (1) changes in the bark color of birch trees that absorb large amounts of dust and soot in industrial areas and (2) the percentage of abnormal (writhen, dwarf, and so on) trees; designing scales upon which these characteristics could be evaluated (e.g., the bark can be light-colored, darkened, or dark; the trees can be tall, short, or dwarf) and drawing an ecological map of the Moscow districts involved;
2. Writing the draft of a legal document that would stipulate the rights of various animals, plants, and other life forms, drawing upon the articles of the Russian Constitution that deal with human rights
3. Collectively deciding (and reporting the decision to the teacher) whether a woman who attempted to kill her husband in the state of serotonin deficiency-related depression was to be punished or subjected to compulsory medical treatment in order to improve her brain chemistry.

The whole student group was subdivided into two teams with approximately equal numbers of students. One of the teams implemented the more traditional hierarchical (bureaucratic) principle. It had a boss who was superior to the heads of the three subgroups. In accordance with the tasks given by the teacher (items 1–3 listed above), the three subgroups were called the Eco-Assessment Subgroup; the Biolegislation Subgroup; and the Rehabilitation Subrgoup, respectively. Each subgroup contained 5–6 students.

The other team was a hirama-type network (see Figure 7). It had no boss and was not subdivided into subgroups, but it contained three partial leaders, each dealing with one of the three tasks. These leaders facilitated and guided the activities of the whole team in terms of each respective task, and they subsequently recorded the results. The creative partial leaders in the networked group were responsible for the following subproblems whose solution involved all network members in the classroom: (i) *Estimating the Environmental Pollution of the Tested District of Moscow; (ii).Writing the Text of the Ecological Constitution;* and *(iii) Resolving the Dispute over the Punishment for Attempted Murder* (see item #3 above). All team members could choose the partial leader to deal with at any given moment; the psychological leader of the network promoted the creative work on all three tasks, trying to make sure that no partial leader was left without support and that all three tasks were efficiently completed. Finally, each team orally presented the results of its creative work. In compliance with the organizational principles of each team, it was the boss who reported the results of the bureaucratic team's work, and the external leader who presented a talk concerning the progress made by the hirama-type team.

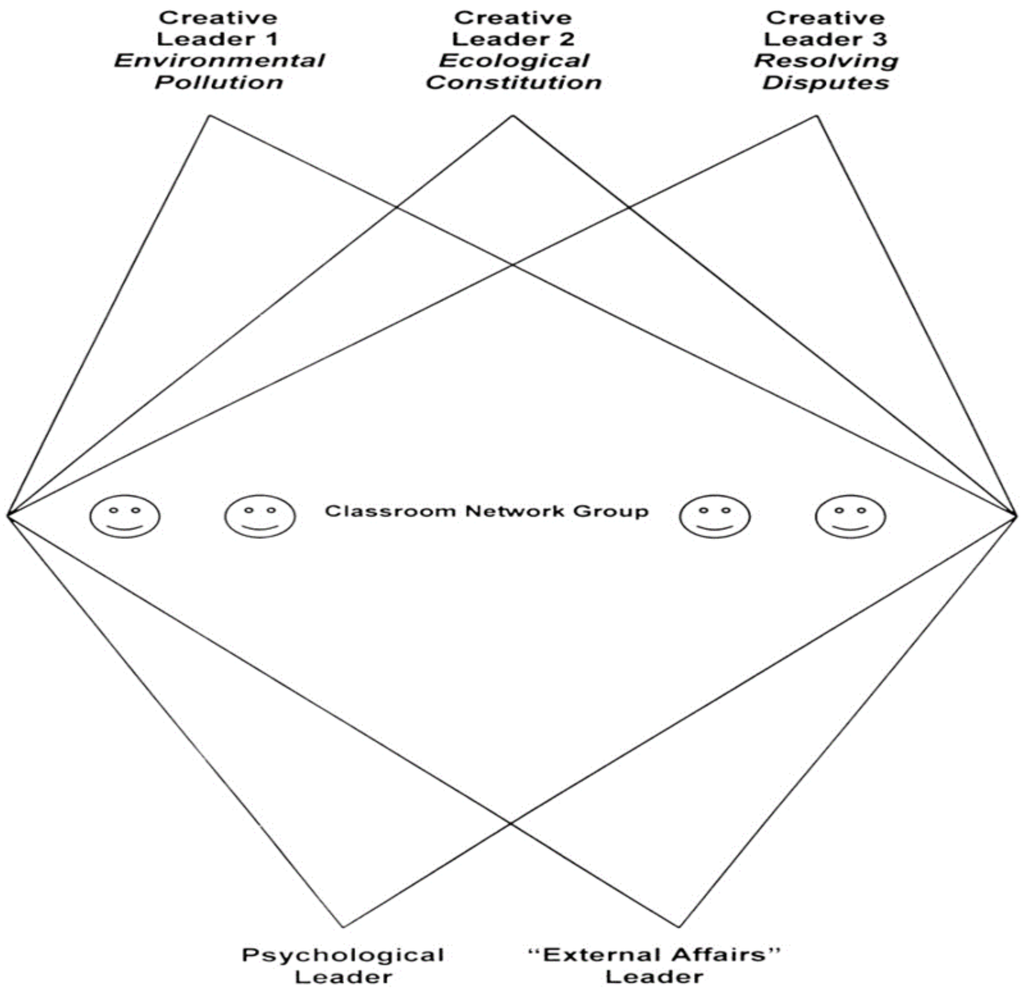

Figure 7. A network structure established in the classroom in order to carry out a creative task concerning the environment

In the following, I compare the efficiency and creativity of the work of the two teams (based on my work: Oleskin et al., 2001):

- The bureaucratic team spent less time completing most parts of the assignment than did the network; the documents containing the results of the bureaucracy's work looked more official, accurate, and neat (particularly the legend to the ecological map of Moscow's districts) than those produced by the network.
- However, the network was more creative, and its documents contained more interesting ideas compared to those of the bureaucratic team (the same trend manifested itself during my classes on a different subject, *Molecular Basis of Behavior,* Oleskin et al., 2001). The network made a more humane decision regarding the attempted murder case: the woman was to be released from prison and to undergo compulsory medical treatment for serotonin deficiency-related problems. In contrast, the "bureaucrats" condemned the criminal to 1 year of prison followed by compulsory treatment. The network produced a more biocentric document concerning the rights of the biosphere; they called it the Constitution of the Biological

Federation, in an analogy to the Constitution of the Russian Federation. The bureaucracy created a more anthropocentric document prioritizing the interests of humans over those of other biological species.

- The students that lacked sufficient experience with respect to the network-specific work style considered the presence of several creative leaders in the network to be confusing; the hirama's successful work was, to a large extent, dependent on the assistance of the teacher who performed the role of the organizational leader in the hirama (see 1.2.2), while the "bureaucrats" were more independent.
- The successful performance of both teams was also crucially dependent on the organizational skills of the people who played the key roles. The efficient work of the bureaucracy required the organizational skills of the boss; the psychological leader's efficient performance was crucial to the hirama's success.

It should be emphasized that these findings are consistent with the data available in the literature on decentralized networks and hierarchies such as bureaucracies. A bureaucracy operates in a more orderly fashion; it is more efficient in dealing with clearly formulated tasks and particularly with routine work. A network tends to outperform a bureaucracy when carrying out more challenging, fuzzy, innovative projects, especially if faced with a dynamic, turbulent environment where the development trend is difficult to predict (Mescon et al., 1986).

The DNS scenario was also used during classes on *Genetic Engineering: the Pros and Cons* at some departments of Moscow State University. The students set up a networked team with three partial creative leaders performing the following functions:

- Leaders 1 and 2 collected arguments presented by all students in the group for and against genetic manipulations, respectively;
- Leader 3 helped students criticize both kinds of arguments and produce a well-balanced, unambiguous final document.

The students were encouraged to interact with any of the leaders, depending on whether they supported genetic engineers, protested against their activities, or preferred a middle-ground attitude.

In a similar fashion, network structures can be established to facilitate interactive teaching during classes in various subjects at a school or college. Teachers can vary both the organizational pattern and the subjects, which can include, for instance, environmental concerns, issues in biomedical ethics, or problems caused by the ineptness and corruption of the state apparatus.

Irrespective of the subject dealt with by a network structure (team, workshop) in the classroom or a college seminar room, students' "creativity is closely related to opportunities for working collaboratively with their peers" (Davies et al., 2013). An additionally important positive factor is the development of a "supportive relationship with the teacher" (Ibid.) who actually plays the role of a network-style partial leader, a "hub".

At this point, the applications of DNSs in terms of *health care reforming* should be revisited. The following example deals with medical education. To re-emphasize, networked teams can be set up directly in the classroom. The teacher provides the students with necessary literature and sets the agenda for a role-playing game. For example, the students deal with the *Norms of Behavior of Health Care Workers with Regard to Psychiatric Patients*. The specific task is to take care of schizophrenics in a hospital ward.

If a hirama-type DNS is preferrred, the student team should include subproject leaders. Either the teacher, or the students themselves subdivide the whole project into subprojects. The subprojects might be concerned with the following subjects:

- *Ethical Norms to Be Obeyed by Health Care Workers while Dealing With Patients*
- *Relevant Legal Regulations*
- *Methods of Nurturing Patients*
- *Ways of Providing Spiritual Support for them*

The creative partial leaders that deal with these issues aim to stimulate, guide, and document the activities of the whole team with regard to each of them. All hirama members are free to join each of the partial leaders, but it is the job of the psychological leader to ensure that each subproject is under development and receives sufficient attention. The external leader's job includes reporting the hirama's results to the teacher.

Apart from hiramas, of paramount importance in terms of interactive education are *neural network* analogs (see subsection 2.2.6 for the neural paradigm) that are characterized by collective information processing, decision making, and learning/training. Emphasis on this paradigm would encourage parallel information handling by creative subgroups within the whole network composed of school/college students. Similar to a neural network, a network composed of students can begin to piece together the solution of a given problem (as proposed by the teacher) on the basis of fragments supplied by individual students and creative subgroups. In terms of the quasi-neural scenario of a student network's operation, special attention is to be given to the creative learning at the levels of the individuals, subgroups, and of the whole multilevel network as a "collective brain". While dealing with a problem/task, students in the classroom can simulate the operation of an artificial neural network such as the perceptron. Like this ANN, students can form several distinct "layers" (i.e., subgroups). One subgroup can specialize in collecting task-related information, in an analogy to the perceptron's input layer. Another subgroup can process the information received from the "input layer", i.e. function as the "hidden layer". A third subgroup—the "output layer"—can generalize and verbalize the result obtained by the "hidden layer" subgroup and report it to the teacher. The scenario would obviously be still more interesting if the "output layer" could send messages back to the "input layer" and the "hidden layer", providing guidelines for their activity on the basis of the result already obtained. This would transform the "neural network" composed of students (as neuron analogs) into a Hopfield-type recurrent network structure (see Figure 4, B in subsection 2.2.6)..

6.3. Network structures of educational activists. Educators, including reformers of the education system, could form network structures at the local, national, and international levels. This would help them maintain business contacts; exchange ideas and educational developments; and, to an extent, coordinate their efforts. Network structures (associations, organizations, etc.) can defend the professional interests of teachers and other people (ranging from lab assistants to theoreticians, who are conceptually developing innovative teaching techniques) that are involved in education. This is of paramount importance for countries where the funds allocated for education are currently being reduced, and teachers may face unemployment or a decrease in their salaries. Network structures can use online communication to help educators unite their efforts and effectively struggle against political hierarchies if these hierarchies disrespect educators' rights and ignore the importance of their professional activities. Organizing educators' conferences and networked workshops seems to be an efficient strategy of collectively coping with problems faced by educators (including teachers' salaries and standards of living), as well as promoting the professional development of educators, including familiarizing them with modern interactive teaching techniques (see above).

International network organizations/movements that deal with educational issues are exemplified by the *Commission for Biology Education (CBE)*, which was established under the aegis of the *International Union of Biological Sciences (IUBS)* in the early 1970s. It develops innovative educational methods including interactive teaching/learning techniques, produces innovative syllabi concerning biology-related subjects, and defends the professional interests of biology teachers worldwide, with special emphasis on eradicating "bio-illiteracy" (a lack of basic biological knowledge). The CBE's main gal is "to formulate, initiate and facilitate effective methods of improving education in the biological sciences and allied fields, including the applications and implications of biological studies" (CBE (Commission for Biological Education), 2019). The CBE holds international conferences and provides guidelines for improving education worldwide, particularly in the form of published books devoted to educational issues.

Of note in this context is the *Society of German Natural Scientists and Physicians* (Gesellschaft Deutscher Naturforscher und Ärzte, GDNÄ, 2020) that brings together scientists from many disciplines to discuss new developments in natural sciences, medicine and technology and makes important contributions in terms of reforming the educational system as related to scientific research and training. In Russia, special hopes should be pinned on the *Moscow Society of Natural Scientists* that has branch offices in some Russian towns and regions.

In an analogy to the business sphere, educational network structures can be established at many different levels, apart from classroom student teams. As far as the macro level is concerned, DNSs can result from forming alliances among educational institutions (universities, colleges, etc.). Such networked alliances can coexist with bureaucratic hierarchies. For instance, university/college deans can additionally perform the functions of partial leaders in such higher-order networks. Such DNSs would enable less efficient educational institutions improve their performance by making good use of the information and experience that is shared by the other nodes of the same network, by exploring new niches, and by collaborating with more successful institutions that also form a part of the same DNS (V.S. Kapustin, unpublished).

Section seven. NETWORK STRUCTURES AND DIGITAL ECONOMY

The Internet as well as its precursors, Usenet, LISTSERV, and particularly APRANET (used by the Pentagon), were based upon the network organizational principle from the very beginning. Each network cannot be controlled by any central unit and consists of thousands of autonomous computer networks, which can be connected by innumerable links that may bypass electronic obstacles (Castells, 1996).

Information is distributed throughout the Internet in the form of packets that are shipped "from vertex to vertex across the network until they reach their destination" (Newman, 2012, p. 3). The packets are "reassembled into a complete message again at the other end" (Ibid, p.18). The decentralized pattern of the Internet is due to a lack of any single control center. "Protocols and guidelines are developed by an informal volunteer organization called the Internet Engineering Task Force, but one does not have to apply to any central Internet authority for permission to build a new spur on the Internet , or to take one out of service" (Ibid, pp.19-20). The routing of packets to their destination depends on automated negotiation among Internet routers using a system called the Border Gateway Protocol (BGP). The whole system is monitored by specialists lest it should become faulty. However, there is no central control agency, no “Internet government”. “The system organizes itself by the combined actions of many local and essentially autonomous computer systems” (Ibid, pp. 20-21). Similar self-organization patterns are characteristic of diverse other network structures in technical devices, living nature, and human society including the scientific community.

The Internet is a decentralized network structure as a physical network composed of computers as nodes that are linked by optical fiber lines and other connections. However, the question to raise is whether the WorldWide Web including all networks of Internet users is decentralized as well? At an early stage of the evolution of the global “cobweb” (around 1989), Internet users directly communicated via a single center-lacking computer network. However, the development of Web in the early 2000’s changed the pattern, and such giant companies as Google, Facebook, Microsoft, Amazon, and others installed centralized service systems that tried to monopolize the WWW.

The Internet-associated media of present-day China are characterized by a high degree of centralization enabling the leadership to easily get access to the content of most on-line documents. Chinese Internet-dependent facilities widely use live streaming, the “All in-One” principle, and QR codes. Much centralized control is exercised by the ubiquitous *We Chat* supernetwork with over one billion users (Gmelch, 2019) and by *Weibo*, a Chinese analog of Twitter.

Establishing the *Decentralized Web (DWeb)*, an idea discussed at several recent conferences, would probably increase the global web’s reliability, robustness, and noise resistance as well as the capacity to survive without the central node (or despite its failure). In the DWeb, data will be routed within a one-tier computer system, and documents will be identified using their content only, without contacting any central servers (http, https). Inevitably, the Internet tends to become more decentralized if virtual cryptocurrencies are widerly used, especially in terms of the blockchain system (see below). As for network structures formed within the scientific community, the actual decentralization of the WorldWide Web should mitigate serious problems caused by unauthorized access to private data including confidential research documents and commercial R & D projects. A completely decentralized WWW would represent a technical analog of DNSs that should function in the field of scientific research, education, and related commercial projects.

7.1. Network structures based on digital platforms. Needless to say, the advent of *digital economy (DE)* is drastically changing business practices around the globe. DE implies the use of integrated ecosystems composed of digital platforms, i.e. systems of algorithmic interactions among a sufficient number of market agents that are embedded in an IT environment. Information is Resource No. 1 under these conditions. In the digital world, instantaneous online transactions produce multiple economic effects; for instance, goods/service supply chains tend to become significantly more complex. Traditional bureaucracies find it increasingly difficult to come to terms with DE. To cope with this new challenge, bureaucratic business principles should be abandoned, and direct interactions, e.g., among suppliers or dealers, are to be promoted. However, this implies replacing conventional competition among virtual agents by their direct *cooperation* involving horizontal interaction among autonomous agents.

Digital platforms promote what can be called *network meritocracy:* they give capable, meritorious participants a chance to make good use of their capacities; the qualification level and the rank of each of the agents involved are automatically estimated by the system itself (Scherbakov, 2020).

It should be emphasized that DE is predominantly characteristic of markets that involve a large number of agents and an intense exchange of services. Under these conditions, new successful business strategies should be introduced that encourage cooperation rather than competition. Whenever service-related expenses tend to decrease and the complexity of the available service systems tends to increase, online competition may incur disproportionately high costs for those responsible for maintaining necessary online connections. To reiterate, cooperation, i.e. mutually beneficial interaction, should prevail over competition in these circumstances. The business success of an agent involved tends to depend on the number of the agent's cooperative ties with other agents.

Of paramount importance is the fact that DE-promoted cooperation does not implicate any vertical relationships, with one agent merely creating the environment that enables another agent to use a specific service system. With respect to DE, it is much more advantageous for virtual agents to interact on equitable terms, so that each of them makes good use of the services made available by others. Using other agents' services, all agents can offer their own services in response, which are made available for other agents or directly for clients.

Digital technology gives a new impetus to DNSs, and promoting their successful non-hierarchical coordination in a DE-dominated environment by means of various methods (including psychological techniques, see next Section) becomes an important challenging task.

A hypothetical network structure could deal with this challenge. The whole task can be broken down into the following main subgoals to attain:

- Developing an adequate business model that would work in a world in which information is the main resource and supply chains become increasingly complex
- Decreasing service-associated expenses and securing a high tempo of updating the service portfolio
- Optimizing agent-client interactions under conditions in which "customers are treated as if they were gods" and trade platforms on the Internet have unlimited sizes.

Digital platforms make it possible to locate and purchase any kind of goods in any part of the planet. State borders and other boundaries are easily crossed, any specific features of national cultures are disregarded, and any political, linguistic, regional, and other barriers separating people are overcome. This promotes an important trend that is characteristic of most decentralized networks: "Networks tend to ignore territorial boundaries and actively communicate with 'outsiders'" (Oleskin, 2014a, p.67).

DE facilitates another major trend in the development of DNSs: they promote a *nonmarket, quasi-socialist* economic system. Intellectual production created on digital platforms is publicized and gratuitously made available for other users; modern-day digital culture tends to dissuade people from staying in their individual dens and is increasingly supportive of a communal, collectivist lifestyle. "The frantic global rush to connect everyone to everyone, all the time, is quietly giving rise to a revised version of socialism. Communal aspects of digital culture run deep and wide. Wikipedia is just one remarkable example of an emerging collectivism—and not just Wikipedia but wikiness at large… Widespread adoption of the share-friendly Creative Commons alternative copyright license and the rise of ubiquitous file-sharing are two more steps in this shift. Mushrooming collaborative sites like Digg, StumbleUpon, the Hype Machine, and Twine have added weight to this great upheaval. Nearly every day another startup proudly heralds a new way to harness community action". (Kelly, 2009). The network quasi-socialism issue will be revisited in Section 11 on network ideology below.

7.2. Decentralized blockchain systems. A decentralized scenario is actually used in blockchain systems. Each block in them contains a cryptographic hash of the previous block, a timestamp, and transaction data (generally represented as a Merkle tree), which enables verifying every block. A blockchain is resistant to any modification of its data because the data in any given block cannot be altered without changing all subsequent blocks. A blockchain system is considered "an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way" (Iansiti & Lakhani, 2017). Other important principles obeyed by a blockchain include openness, transparency, and trust that enables accumulating social capital, which is of paramount importance for DNSs in general. Client-oriented programs concomitantly running on many computers form a one-tier network; all nodes of the DNS enjoy equal rights and are self-sufficient. The operation of blockchain systems is promoted by using cryptocurrencies such as the Bitcoin or the Ethereum, although a blockchain can work without them.

In China, a combination of network and hierarchical structures is in operation with respect to blockchain systems. Under the auspices of the People's Bank of China, blockchain systems have been given official ranks. *EOS* is the top-ranking system. Despite the guiding influence of the centralized banking hierarchy (its chaperone-like action, see Section 9 on social chaperones), this blockchain system is decentralized per se. It is based on 21 interacting hubs; twelve of the hubs are in China. Of note is also the system called *Ontology* (with 7 hubs) that has the third rank, as well as *Neo* (with 7 hubs) that has the seventh rank (Kshetri, 2019). The successful operation of blockchain systems in China is promoted by relying on inexpensive energy sources, which facilitates using virtual currencies, including, e.g., Bitcoin mining (Schmitz, 2020).

Section eight. NETWORK STRUCTURES AND PSYCHOLOGICAL TECHNIQUES

Network structures including those associated with digital platforms can increase their efficiency and the motivation of their members by means of psychological techniques that promote group cohesion and the dominance of group-level goals and values over the individual interests of network members. Of significant importance are the following psychological techniques:

- Brain storming originally suggested by Alex Osborn in 1941 include several main stages. "Firstly, a goal is defined to understand what the main purpose of brainstorming is… Furthermore, different aspects of the problem or situation are explored and we list down ways to overcome the challenges. There is no structure in brainstorming, and no idea is considered wrong. All ideas are noted during the brainstorming sessions, and some can even be clubbed together" (What is Brainstorming, 2021).
- Game techniques including role-playing games during which the participants can, e.g., imitate the behavior of a person. Alternatively, they can act the role of some organ of the human or animal organism, of an inanimate object, or even of an abstract notion such as fear, death, or uncertainty (Vachkov, 2001, p.60).

As noted above, living nature has invented at least seven different paradigms of network structures. Emphasis could be placed, for instance, on the *cellular paradigm* (see subsection 2.2.1). Of relevance is the function of the biopolymer matrix that cements all cells in a colony, biofilm, or tissue and facilitates the coordination of their behavior. To reiterate, a biofilm analog is a human DNS consolidated by a set of unifying ideas and behavioral norms, by the intellectual matrix of this decentralized network. While the cell walls and/or outer membranes of microbial cells merge to form the biofilm matrix, psychological boundaries between individuals in a close-knit network tend to become less clear, and all network members seem to become psychologically similar.

Such partial merging of several personalities within a network (tconfluence) may take place if brainstorming sessions are held; it is promoted by psychological techniques that prioritize group values and group unity symbols with which networked group members identify during such brainstorming sessions. Group unity symbols are exemplified by various animals that cause special feelings shared by all network members, evoking totem cults in primitive human societies. Network cohesion is facilitated by techniques that make use of evolution-molded behavioral predispositions and biological needs. It is known from ancient times that collective meals promote group cohesion. It is to be recommended, therefore, that a brainstorming session should be accompanied or followed by a social breakfast, a lunch, or even an evening party for the whole network.

Importantly, the aforementioned psychological techniques enable coordinating the behavior of network members and synchronizing their activity rhythms even though the network has no single leader. This situation is a variation on a more general theme: the quest for factors enabling the synchronization of network node behavior despite the lack of a central pacemaker.

Yoshiki Kuramoto (1984) developed a mathematical model concerning a system of coupled oscillators whose natural rhythms are randomly distributed over a certain range. The model can be applied to the behavior of network nodes (Arenas et al., 2008). It predicts the entrainment (synchronization) of the nodes of one network, provided that their original rhythms are not too different in terms of their tempo and initial phase. If the difference is below a certain threshold, the network is expected to contain clusters of interacting nodes with synchronized behavior. A further decrease in the initial difference between individual node rhythms makes all nodes of the network behave in sync with one another.

Applying the cellular paradigm to network structures in human society actually emphasizes the belonging of each network member to the whole superindividual structure. Importantly, network structures are not composed of individuals only; they possess their own superindividual will. As already mentioned, the set of ideas and values accepted by a network---the matrix---represents the mental condensate that is produced by human thoughts and emotions and has its own independent personality.

A decentralized network structure is comparable to a primitive hunter-gatherer band that was based on an extended family and was probably widely spread among Cro-Magnon people or our more distant ancestors. The primitive band helped its members satisfy a number of important human needs and desires (that are so archaic that they are partly similar to those of apes and other primates; this part of the work is based on Dr. Larisa Kolesova's unpublished data):

- Need for identification with a particular social group with its basic values
- Need for protection against external dangers: a decentralized network hedges individual risks and promotes a feeling of safety at the individual and collective level (including territory protection)
- Desire to behave altruistically, in a self-sacrificial way, for the benefit of the whole networked group
- Desire to submit to a sacral leader that in a decentralized network cannot become a boss or a dictator and merely personifies the ideological matrix of the network, like the spiritual leader of some hiramas (see subsetion 2.1 above)

- Need for communication with those belonging to the other gender and for mating behavior; this need can be satisfied without quitting the network and it may be an additional incentive for efficient team work.

A complete satisfaction of these and other basic needs calls for efforts to be made at the level of the whole network (this is the responsibility of the psychological leader in a hirama-type network). Sophisticated psychological techniques are to be adapted for DNSs and implemented in them. Of note is *Neuro-Linguistic Programming (NLP)* that anchors desired psychological effects (e.g., efficient work on a project) to basic behavioral predispositions, which were in a large part characteristic of our evolutionary ancestors.

Importantly, the roles of partial leaders in networks should be in conformity with the psychological types of the incumbents of these roles. Much promise seems to be held by a personality type classification that is based on the predominance of particular kinds of neurochemicals and hormones. This classification was put forward by Helen Fisher (reviewed, Brown et al., 2013) and includes the following types:

1. Individuals characterized by the dominance of brain structures (e.g., substantia nigra) that contain dopamine and/or norepinephrine; these people are inquisitive, vigorous, and creative; they are predisposed to function as partial *creative leaders* dealing with one of the subgoals that form a part of the general goal pursued by a hirama-type DNS
2. Individuals with a brain that predominantly depends on serotonin-containing structures, such as the ventrolateral prefrontal cortex; they are cautious and sociable; these individuals are not expected to become partial leaders but they seem useful as *generalists* that collaborate with several different leaders in a network
3. Individuals characterized by the dominance of brain structures (e.g., the inferior frontal gyrus) that are regulated by the female hormones estrogens and oxytocin; they are trustful, communicable, and empathetic; therefore, they may be useful as *psychological leaders* or, alternatively, form a part of guidelines-providing *chaperone* network (see next section).
4. Individuals characterized by a high activity of the male hormone testosterone, which predominantly interacts with the occipital and parietal lobe of the brain cortex; they are forceful, strong-willed, and often have mathematical abilities; these individuals may become efficient *organizational leaders* at the initial stage of a new network's lifecycle; however, testosterone people may impede the operation of a more mature network because they are predisposed to establish hierarchical, and not decentralized, structures.

Since much attention has been given in this section on the cellular paradigm of network structures, emphasis should be placed on the people with dominant dopamine/norepinephrine brain systems. Such inquisitive people can facilitate the merging of network members' personalities into a single creative field (based on the network's matrix) that promotes the solution of complicated problems. An imaginary network structure could be aimed at organizing digital transactions in business. In all likelihood, it will be dopamine—norepinephrine people who will come up with untrivial, seemingly crazy scenarios of profitable business projects even if the available resources are quite limited.

Finally, it should be stressed that the predominant neurochemical picture of the brains of network members, including those focused on scientific research or related commercial R & D, crucially depends on the state of the *microbiota*, i.e. the symbiotic microorganisms that inhabit our body and especially the gut. The microbiota produces neuroactive substances that---directly or via the peripheral nerves and he endocrine and immune systems---influence the brain and, accordingly, the psyche. The gut microbiota includes microorganisms that produce considerable amounts of DOPA, the direct precursor of dopamine. Such DOPA producers are exemplified by lactobacilli contained in fermented dairy products such as yogurts as well as by the permanent gut inhabitant *Escherichia coli* (reviewed, Oleskin & Shenderov, 2020). Upon its synthesis by the microbiota, DOPA crosses the gut-blood and the blood-brain barrier. In the brain, DOPA converts to dopamine that produces creative work-promoting effects, including causing a feeling of happiness to the point of inducing euphoria.

Regardless of the psychological techniques that are applied and the biosocial predispositions that are activated, a successful operation of network structures, including those in the virtual realm, can be facilitated by *chaperones* that are discussed in the next section. Their main goals include the promotion of decentralized network structures in all spheres of society in which they are expected to be useful; in addition, it is chaperones that can develop and implement efficient psychological techniques aimed at stimulating their creative work.

Section nine. SOCIAL CHAPERONES

Despite the specific characteristics of human society as a unique system, many trends and patterns of its development are to a certain extent analogous to those of biological systems. As mentioned above, a large number of biological systems have analogs of human network structures.

The development of many network structures both in biological systems and in human society chiefly depends on their self-organization rather than on external controlling agents. Self-organization proceeds at the biomolecular level: a purified denatured (i.e., having a dysfunctional conformation) ribonuclease enzyme spontaneously reacquires the functional conformation, so that its folding pattern enables its normal operation. Spontaneous self-assembly is characteristic of tobacco mosaic virus particles and bacterial ribosome subunits.

In biological systems and human society, spontaneous self-organization successfully proceeds as long as it does not exceed certain limits; otherwise, a corrective external influence is necessary. In biopolymers, interactions within and between polypeptides and other molecules should be controlled in order to decrease the probability of forming “wrong structures” that do not perform the functions which are necessary in the given situation (Ellies et al., 1991). In similar fashion, research on human network structures including those in business revealed that many networked organizational forms actually fail to fulfill the functions for which they are established (Podolny & Page, 1998).

This invites a more general discussion regarding human society. The global spread of network structures, i.e., the network revolution, takes place irrespective of the presence of controlling agents. However, in an analogy to uncontrollably folding biological molecules, a networks-based social system without regulatory bodies risks becoming dysfunctional and destructive, due to its inadequate organization, corruption, or the influence of detrimental forces. They are exemplified, in human society, by the network structures of drug dealers or terrorists, including Al-Qaeda or the Islamic State.

Many molecular biological systems contain *chaperones* that, in the biological sense, represent molecules regulating the assembly, folding, and functioning of other biological molecules[8]. As far as protein molecules are concerned, various types of chaperones are responsible for the correct folding of polypeptide chains upon their biosynthesis, their integration

[8] Some biological molecules include parts that control their own self-assembly, i.e., represent internal chaperones.

into higher-order structures (oligomerization), and the adequate modification of the resulting structures during their transfer across biological membranes and subsequent operation. The biological term chaperone was first suggested at a scientific conference in Copenhagen in 1987 and shortly thereafter mentioned in an article published in the journal *Nature*. However, the original meaning of the word “chaperone” in English is “an older person who accompanies young people at a social gathering to ensure proper behavior” (Mariam-Webster, 2021).

Chaperones are mandatory for many molecular biological systems; otherwise, uncontrolled protein folding may pose the risk of forming inadequately functioning structures. This is due to the fact that numerous weak molecular interactions should be properly adjusted for maintaining proteins in their functional state (Ellis et a., 1991).

9.1. Main functions of social chaperones vis-à-vis network structures. *Social chaperones* (intermediary structures) are analogs of molecular biological chaperones. They can perform a number of important functions with respect to decentralized networks, including those in the scientific community.

9.1.1. Promoting the development and dissemination of decentralized network structures in all spheres of society in which they are useful. Of paramount importance is the creativity-stimulating capacity of network structures, particularly those dealing with ambiguous issues that require innovative ideas. To a much greater extent than hierarchies, networks provide, apart from information resources, emotional support for their members. Members tend to identify with their network, which implies accepting and internalizing the main goals, behavioral norms, and special ethical rules of the network. Even if the reason for setting up a network is entirely pragmatic, such a social body tends to evolve into a close-knit quasi-communal structure. Whenever a virtual network (e.g., a webchat or an Internet-club) becomes sufficiently stable and long-lived, its members often develop amazingly intimate trust-based informal relationships. These relationships involve many different aspects of the members’ lives. Such multi-faceted relationships help the networks successfully crunch multi-faceted problems.

9.1.2. Familiarizing network structure developers in various spheres of society with the whole spectrum of different organizational types of networks. Biology can provide much food for thought for network structure developers in human society, including the scientific community. Despite the obvious differences between humans and other forms of life or between human social systems and biosocial systems of various non-human biological species, biological network paradigms undoubtedly can be considered useful building blocks for developing the scenarios of decentralized networked business enterprises, networked associations of citizens within the framework of civil society, or teams of artists. The pluralism of the organizational principles of network structures in living nature is highlighted by the fact that there are at least seven different network paradigms, including the aforementioned cellular (microbial), rhizome (fungal), neural, modular (cnidarian), equipotential (fish), eusocial (ant), and egalitarian (ape) paradigm. Plausibly, other (non-network) structures, such as centralized hierarchies and (quasi-) market structures that also exist in living nature[9], can be also used in terms of combined organizational scenarios. Chaperones can make good use of already existing social structures that

[9] The discussion of biological prototypes of hierarchies (typified by wolf packs) and quasi-market structures (exemplified by lizards constantly competing for territory) is beyond the scope of this work (see Oleskin, 2014a, b).

successfully use, combine, and modify various network paradigms. They are exemplified by the Zed Books publishing company (Great Britain)[10]. Chaperones should help networks chose the optimum paradigm (or paradigm combination/modification) in a given situation (Rothwell, 2016).

9.1.3. Mediating interactions between network and non-network structures and, in more general terms, *interactions between any structures belonging to different organizational types,* e.g., *between networks and hierarchies, networks and (quasi-)markets, or hierarchies and (quasi-) markets.* Chaperones also may ameliorate interactions between several structures of the same type, for instance, between several network structures. Importantly, even an advanced network society will still include non-network structures in those spheres of society where they are necessary. Despite the spread of decentralized networks in civil society, a centralized political hierarchy will still perform the nation-consolidating function that involves developing the national ideology and providing guidelines for the country's interaction with other countries around the globe as well as furthering the nation's political, economic, and financial interests. Promoting constructive interactions between decentralized networks and hierarchies including bureaucracies, networks and (quasi-) market structures, and also productive communication among decentralized network structures should involve intermediary bodies, and this function should also be fulfilled by social chaperones. Intermediary bodies that are responsible for the interaction between the networks of civil society and the hierarchies of the political systems include *think tanks.* They are exemplified by nonprofit political organizations that evaluate political projects and develop political guidelines (Rich, 1999). Think tanks consist of expert teams carrying out educational, evaluative, creative, communicative, and promotional projects. Recently, predominantly decentralized network-type structures in the USA, such as the RAND Corporation, the Brookings Institution, and Hudson Institute have demonstrated their efficiency in terms of political planning. Their facilitative role is based on elucidating the linkages between scientific knowledge and political power as well as between science & technology—and political projects. For instance, the RAND Corporation provides its long-term recommendations for politicians on the basis of theoretical studies in various areas of research; these recommendations cannot be prepared at the offices of political institutions because their staff predominantly concentrates on present-day tasks and narrowly-specialized problem solving. Think tanks are independent social bodies that mediate the interactivity between the political hierarchy and horizontal networked teams of scientists/scholars. This independence is highlighted by their characteristic customs and rituals. One of the customs of the RAND Corporation was that its staff members went to a swimming-pool during the lunch break; their dress was casual; the atmosphere was relaxed; and the staff was communicable (Dixon, 1972).

[10] The *Zed Books* company had no single boss, all its staff members enjoyed an equal status (were paid equal wages) and tried to be maximally similar to one another. The author of the article cited (Rothwell, 2016) was even worried about their becoming identical clones. In this respect, the company resembled a leaderless, equipotential fish shoal. However, since the company 's size was quite small (12 people), it was also similar to an egalitarian troop of chimpanzees that is typically composed of a limited number of individuals. The work cited also references the *Gore* network that is famous for having developed Gore Tex, a waterproof, breathable fabric membrane. This networked team seems to conform with the "ant paradigm". Like Gore with its ~10,000 associates, an ant family comprises a number of small worker teams that have temporary task-oriented leaders.

9.1.4. Monitoring and assessing currently active network structures in terms of their goals, behavior norms, etc. To reiterate, the establishment of a predominantly network-style society around the globe should be called the *network revolution*. The emergent new social and economic system can be referred to as the *network (reticular) social formation* (Oleskin, 2014a, 2016). Optimizing the functioning of the novel social formation requires the involvement of social chaperones. Their goals should include regulating the ongoing network revolution on the global, national, and local scale as well as improving humankind's quality of life by promoting beneficial networks, especially those with a humanitarian agenda; and counteracting the spread of detrimental networks associated with crime, corruption, and terrorism. Social chaperones can make the new developing social formation more humane by fostering peace-making, environmental, health-promoting, and other humanitarian networks and facilitating their interactions with non-network (hierarchical, quasi-market) structures.

9.1.5. Subtly influencing people's attitudes and aspirations. Chaperone networks using online facilities have already proven their efficiency in promoting or discouraging particular attitudes and goals among the people at large. A networked team of astronomers, geophysicists, climatologists, and evolutionary biologists called the Virtual Planetary Laboratory (2012) at the University of Washington is currently studying how to detect exoplanetary habitability and their potential biosignatures. This network structure seems to have the potential of inspiring multitudes of people with new fascinating goals such as exploring the distribution of habitable worlds in the universe and searching for new "humankind's homes". A promising candidate is *Proxima b,* a planet rotating around the star Proxima Centauri, our sun's nearest known neighbor at 4.2 light-years away.

9.2. Different strategies of developing chaperones. It should be re-emphasized that social chaperones can be organized as decentralized distributed networks that are responsible for stimulating and educating other DNSs. The target network structures may be narrowly specialized (like a network of public restrooms on the Lenin Street in the town of N) or have a very broad focus, dealing with the cardinal issue of the future of humankind and the planet Earth in the Solar System. Such regulatory network structures should include prominent scholars, educators, and experts in socially and politically important matters. In addition, such chaperone network structures could incorporate social activists, journalists, artists, and the clergy.

There are at least three different strategies of establishing and promoting chaperone networks:

- The *bottom-up strategy* that is based on establishing socially/politically active associations of ordinary citizens as exemplified by (savings bank) shareholders, hospital patients, environmental activists, and car drivers
- The *top-down strategy* involving the government's decision to establish creative network teams with regulatory functions, including the aforementioned think tanks aimed at solving ambiguous problems that may require brain-storming sessions
- The *combined strategy* that might be the best option and involves both the elite and the people, the top and the bottom of human society. Let us imagine that the World Health Organization (WHO) has decided to use the top-down strategy in a town with a COVID-infected population. Active citizens, in their turn, should now use the bottom-up strategy and take the responsibility for coordinating the efforts of all relevant health care, educational, and scientific research institutions.

The reason why the combined strategy might be the optimum option is that chaperone networks should not be set up only by a decree of the government; otherwise, they risk becoming just puppets whose strings are pulled by the puppeteers of the political elite. Nonetheless, chaperone networks should not be formed only by ordinary citizens because they may lack the necessary qualifications and be too narrow-minded. The top-down and the bottom-up pathways dialectically interact in the combined strategy.

All these considerations apply to social chaperones regardless of their country and the social/political environment in which they provide guidelines for the development of network structures that, to re-emphasize, hold especially much promise in terms of scientific research and the commercial applications of its results.

However, there are specific additional country- or region-specific functions to be performed by chaperone networks. A priority task for chaperones in post-communist countries, exemplified by Russia and China, could be facilitating the interaction between

- *Market-type structures* (characteristic of the realm of business) and decentralized network structures in which informal relationships dominate over business communication and the importance of business activities is diminished by the prevalence of a commune-style ethic
- The *hierarchies* of both the scientific community per se and, whenever of relevance, of the political system---and decentralized network structures that are based upon the nonhierarchical principle or at least promote horizontal relationships

In addition, chaperones should be tasked with legalizing and institutionalizing useful network structures, as well as familiarizing their members with the aforementioned biological paradigms of their organization. If no guidance is provided by chaperones, networks will grow ("mushroom"[11]) in human society but predominantly yield human analogs of toadstools—including criminal and terrorist networks—rather than useful mushrooms. While stimulating the development of beneficial networks with humanitarian, charitable, scientific research-related, health-promoting, environmental, or educational goals, social chaperones should counteract the spread of detrimental network structures.

It is imperative that unprecedented decisions should be made to change the law and even a country's Constitution in order to legalize networks in various spheres of society as exemplified by networked enterprises and local business clusters (Smorodinskaya, 2015). Social chaperone structures should also acquire a legal status. This will give a new impetus to the interaction between power structures and ordinary citizens in any country around the globe and obviously give the countries involved new chances and options in political, economic, cultural, and, importantly, scientific terms.

In order to successfully monitor and promote the development of decentralized networks both at the local, regional and global level, social chaperones should exert a sufficiently strong social and political influence on power structures and the leading representatives of the business world. In this case, practical measures can be efficiently taken whenever an authoritative statement is made by a chaperone, e.g., *This network structure is sufficiently useful to be promoted* or, alternatively, *This network is detrimental and must be disbanded or at least reformed*.

To reiterate, the spread of decentralized network structures in the scientific community and other spheres of society is not expected to result in completely eliminating other types of social structures, such as hierarchies or (quasi-)markets. A prerequisite for the successful solution of

[11] This analogy seems sufficiently meaningful because the growth of fungal mycelium is in conformity with the rhizome paradigm of biological networks

many socially important problems including, notably, reforming scientific research institutions, is productive interaction between different types of structures. Therefore, some emphasis should be placed on the role of social chaperones in terms of promoting useful communication between hierarchies, networks, and (quasi-)markets (see item 3 in the above list).

Moreover, structures can interconvert. If time is considered the fourth spatial coordinate, then transformations of structures over time and their interactions at a given moment are variants of the same phenomenon. Different structures are located at different spatial or temporal points of the space-time continuum. Various systems in the biological and the social sphere display a wide variety of transformation/interaction patterns. In human society, these transformations or interactions partly result from efforts that have been intentionally made by the people involved. "Agents choose to cooperate or not in a market, hierarchy, or network as a function of their individual attributes and their beliefs about the attributes of the other agents with whom they may interact" (Jung & Lake, 2011).

Louis Meulemann (2008) suggested that "meta-governors", i.e. social chaperones in our terms, should "design and manage situationally optimal mixtures of governance styles", i.e. types of organizational structures. Chaperones dealing, e.g., with public policy issues, are to "combine governance style elements", "switch between governance style elements", and "maintain the mixture". For example, "during a crisis, a hierarchical command and control style should be in place, because time is crucial and quick decisions are needed". After the crisis, market-type organizations are preferable, while in a crisis-free period, "parties cooperate in the form of a network and work on enhancing mutual trust and understanding" (Meulemann, 2008, p. vii).

Obviously, using social chaperones is not tantamount to exercising any kind of hierarchical control over network structures. Chaperones are not empowered to control other networks; they can only subtly stimulate socially useful DNSs by subsidizing or morally supporting them; they can also organize campaigns to ostracize potentially detrimental networks such as some sectarian DNSs.

An important aspect of the activities of chaperone networks could be counselling other network structures throughout all stages of their life-cycle (cf. the discussion on network incubators in Subsection 3.4) ranging from the birth of a new DNS to its maturation and even to the liquidation of a defunct network. Network structures are expected to consult chaperones with respect to such problems/issues as recruiting new network members, allocating resources for a developing network, distributing functions among network members, setting forth the formal and informal rules of behavior of network members vis-a-vis one another or external partners, drawing up the cost-benefit balance sheet, etc.

In functional terms, chaperone networks are partly analogous to *regional management (RM)* bodies in some European countries. RM bodies are characterized by diverse organizational patterns and often represent bureaucratic administration-independent teams that promote the formation of network structures. Their mission is to provide guidelines for decentralized *local action groups (LAGs)*. LAGs typically prefer a multileader style (*Multi-Führungslinien-Stil* in Germany) and include local governmental officials, university and school representatives, clergy members, farmers, etc. LAG facilitate the designing and implementation of regional development strategies aimed at promoting agricultural production, environmental conservation, and the development of recreational facilities.

LAGs are supported by RM bodies that secure their long-term viability under challenging conditions (Salchner, 2018; Meike Lücke, personal communication). In an analogy to social chaperones, RM bodies behave as network-style coordinators that promote interactions among networks composed of local activists and between them and the officials responsible for local development programs. Many RM bodies are decentralized; they monitor and assess the activities of other local network structures that are involved in promoting the development of agricultural regions in Europe and propagandizing information about such local DNSs in the media.

I suggest that RM-like structures should be widely used in present-day Russia; their potential usefulness is also indisputable in other post-communist countries including China.

Section ten. MERGING NETWORK STRUCTURES INTO MEGANETWORKS: POSSIBLE SCENARIOS

An additional urgent task for chaperones in the currently developing information society with its digital economy is joining together network structures, including those with narrow, parochial agendas such as local associations of frustrated bank clients or the parents of kindergarten-attending children. Establishing multilevel "networks of networks" is an important prerequisite for developing civil society as well as for carrying out large-scale social, cultural, scientific, and environmental projects and motivating the people at large to engage in useful social activities. Many spontaneous network structures are small in size, do not interact with one another, and lack social influence. Importantly, it is only large-scale networks that can be considered as efficient partners by hierarchical structures within the scientific community as well as in other spheres of society.

Carrying out large-scale projects requires joining DNSs into large multiprofile *meganetworks.* Such meganetworks should have multilevel internal structures (representing complex "networks of networks"); they should hold special promise in terms of developing and promoting a new *network ideology* (see next section). They have the potential to deal with fundamental issues concerning the meaning of human life, the improvement of the political regime, our bright future (*Does it really exist? What is it like?*), and the historical mission of humankind (*What is the purpose of our existence on the planet?*) and of all its parts, including nations, ethnicities, social classes and strata, etc. as well as the principles of interhuman relationships and humankind's attitude to life on Earth and to nature in general.

Network structures develop at various levels of society. Apart from grassroots network structures that include, e.g., the inhabitants of a condominium, there are decentralized networks established by governmental institutions and the political elite, exemplified by think tanks that were set up by Franklin D. Roosevelt in the USA. The efficient functioning of such elite network structures can be facilitated by their interaction with grassroots networks that should promote the involvement of the people at large in important national or global projects.

Much promise is held in this context by the *polycentric system concept* that was put forward by Vincent Ostrom (1962) and Elionor Ostrom (2005, 2010). In terms of this concept, political, social, and environmental decisions are made during negotiations that involve political structures at several social levels ranging from local administrative offices to state-level and international bodies. The authors cited provided several examples, including the process of collegiate multilevel decision-making regarding greenhouse emission reduction (E. Ostrom, 2010) and coral cay protection in Palau (Oceania) (Gruby & Basurto, 2014). "The multilevel fractal organization of political networks can actually be 'horizontalized' in such a nested political structure: agents belonging to different levels (e.g., representatives of a local organization, of a state apparatus, and a supranational body) can participate, on an equitable basis, in political decision making. Moreover, they are encouraged to jointly carry out political projects, e.g., those concerned with the environment" (Oleskin, 2014a).

If several network structures should cooperate to the point of merging into a higher-order network, it seems expedient to creatively use prototypical scenarios developed during the course of biological evolution. There are network structures at different levels of human society (micro-, meso-, and macrolevel networks). Likewise, living organisms in nature form associations belonging to different organizational levels. An ecosystem consists of a number of local associations that, in turn, are made up of several populations, which, consist either directly of individual organisms or their subpopulation-level groupings such as demes. The goal of merging several networks into a higher-order decentralized network structure is pursued by biological systems in two different situations:

1. When several networks of the same level combine to produce a structure that also belongs to this organizational level. At the level of a population, i.e., a collective of individuals belonging to the same species, small-size local groups of individuals join into larger groups. For instance, several small bacterial colonies (rafts, microcolonies) combine to form larger colonies or biofilms.
2. When several networks merge into a structure belonging to a higher organizational level. Several populations of different species combine to form a local multispecies community (cenosis). Several local communities constitute an ecosystem.

Natural ecosystems typically operate in a harmonious way, successfully coping with the challenge of coordinating the behavior of many decentralized networks belonging to different organizational levels.

Importantly, the process of combining network structures and forming larger-scale meganetworks in both situations is based on several typical scenarios. They can potentially be creatively used for achieving the goal of promoting network—network interaction in human society. To reiterate, the resulting meganetworks are capable of (i) dealing with large-scale projects exemplified by monitoring the environmental situation on the whole planet, (ii) developing an efficient and influential civil society within the framework of a whole country that can, for instance, urge governmental bodies to promote the reforming of scientific research institutions, and (iii) building up sufficient resistance to giant industrial companies (e.g., if the small networks involved are SMEs that cannot survive competition with industrial monopolists on their own) or to the bureaucracy of powerful academic institutions.

10.1. Contract-based scenario. According to this scenario, two or more network structures make contracts to form temporary project-oriented networked alliances without losing their organizational independence.

As mentioned above, network structures in the microbial realm are typified by biofilms. It is possible that the biofilm of one microbial species forms a product that can be used as raw material (substrate) by the biofilm of another species. A whole second-order network of such microbial biofilms may come into being, in an analogy to the networks of suppliers in networked alliances of business firms as exemplified by those involved in manufacturing the parts of a Boing plane. To re-iterate, some of our evolutionary relatives, e.g., chimpanzees, form loose fission-fusion groups that seem to be based on an analog of the contract-based scenario. Individuals opt to stay together only as long as , e.g., there is sufficient food for the whole group.

In human society, the contract-based scenario is illustrated by *dynamic network structures* in the sphere of business (Snow et al., 1992). They are temporary interfirm alliances that are established for carrying out a project and disbanded after its completion in order to form other temporary alliances. Naturally, such interfirm networks are neither stable nor long-lived.

Let us revisit the hirama model. If several hiramas deal with environmental issues, it seems reasonable to combine them, at least for a limited time, in order to deal with large-scale projects envisaging, e.g., the ecological assessment of the territory of a country. In this situation, several networks join in solving a problem that is considered a subproblem by each of them (therefore, each network includes a competent creative partial leader). For instance, several environmental hiramas working in different regions of the same country find out that the goal *Estimating Pollutant Concentrations and Radioactivity Levels* is on the agenda of each of them, although other agenda parts may be different in different hiramas. The external leaders that are on the staff of each hirama start negotiations that also involve creative leaders specializing in the aforementioned subgoal. This results in the formation of a temporary creative inter-hirama alliance. It may be based on an official contract that does not restrict the autonomy of the network structures (hiramas) involved.

In many DNSs, there is an upper limit on the number of their members, especially if they tend to develop informal, communal-style, or even family-type relationships among these members. This limit is actually imposed by the Dunbar number that is widely used in sociology and corresponds to the number of people with whom one can maintain stable social relationships—relationships in which an individual knows who each person is and how each person relates to every other person. On average, the Dunbar number is about 150 people.

If DNSs increase in size, they may face a crisis that may result in disintegrating the network structure. The problem can be solved by *quasi-externalization* (Sydow, 2010). It may be a general assembly that is empowered to make the decision to separate the network into several autonomous structures with their own partial leaders (if the hirama model is used) that thereupon form a contract-based alliance.

An example is provided by a hypothetical team of IT specialists. The challenging task may be to develop software for transactions involving virtual cryptocurrencies such as the Bitcoin and the Ethyrium. If the original oversized (and perhaps bureaucratic) creative lab breaks down, quasi-extrenalization can be used to set up several small nonhierarchical IT teams that collaborate in terms of the software development project. Their independent work is accelerated by inevitable competition among the teams that, nonetheless, have to cooperate within the framework of the overarching project. To reiterate, such a creative combination of competition and cooperation is characteristic of colonial cnidarian polyps in terms of the modular paradigm in biological network structures (see subsection 2.2.2).

Apart from cnidarians, a similar challenge is faced by the decentralized structures of social insects such as ants. An ant family (a pleiad, Zakharov, 1991, 2005) has its size limit; once this limit is reached, further growth results in *sociotomy*, i.e., the budding off of daughter families. This process involves an interesting combination of the network and the hierarchical patterns. The bigger maternal family tends to form a hierarchy in which it dominates the daughter colonies. Taken together, these families form a hierarchical *true colony*. Subsequently, several true colonies form a higher-order decentralized network structure called a *federation* (Zakharov, 1991, 2005).

10.2. Organismic scenario. As the above scenario of creating large-scale network structures is characterized by the independence of all the partners (smaller networks, subnetworks) involved, it does not secure the longevity and stability of the whole temporary meganetwork.

An organizational scenario aimed at establishing long-lived multilevel networks should envisage them as social analogs of living organisms. In contrast to the aforementioned quasi-externalization, this process is denoted as *quasi-internalization* (Sydow, 2010): several originally independent network structures exemplified by two nonhierarchical research teams decide to merge into one networked organism. There are meaningful biological analogs of this process.

Since antiquity, social bodies including whole states were regarded as organism-like entities, and castes, classes, and other strata were analogized to the organs of these organisms. What are the biological criteria of an organism and what networked bodies in human society possess organism-like properties?

These criteria were succinctly set forth in the work by the Russian biologist Vladimir Beklemishev (1950). Some of his ideas are reformulated below in order to extrapolate them to human social networks:

10.2.1. Formation of organs that function at the level of the whole collective system. In human society, the formation of an organism-like multilevel network implies that the subnetworks it comprises become functionally differentiated and work for the benefit of the whole large network like the organs (the heart, the lungs, the kidneys, etc.) of a biological organism. Therefore, each subnetwork that forms a part of this organism-like network loses its independence.

Organismic properties are characteristic of many structures denoted as *stable networks* in the literature (Snow et al., 1992). They are geographically distributed firms typified by Japanese *keiretsu*, i.e. stable industrial associations composed of small firms specializing, e.g., in various stages of producing cotton clothes as well as by Scandinavian networked alliances of industrial giants such as Volvo, Ericsson, Saab-Scandis, and Fairchild. In the classical work by Powell (1990), the formation of organism-like networks composed of small-size enterprises employing less than 50 people was described in North Italy (Emilia-Romagna)

As for hiramas, their alliances acquire organismic properties if the hiramas become functionally specialized and interdependent within the framework of a second-order hirama. In such a close-knit second-order network, each of the partial leaders is not a person but a specialized hirama. If the hirama dealing with the *Assessment of the State of Plant Ecosystems* project were to become a second-order network, then each of the three subgoals in the list given in Subsection 2.1 above would be addressed by a self-contained hirama. Each subgoal, e.g., *Assessing the Pollutant Concentration and the Radioactive Background,* would be further subdivided into narrower "sub-subgoals" in which specific creative partial leaders would specialize. In addition, each small hirama would include its own psychological and external leaders.

Such multiple-level DNSs are of potential importance for science-based R & D. Let us revisit the project of obtaining inexpensive biogas (Subsection 3.1) that was subdivided into the following subgoals above: (i) screening for microbial cultures that efficiently produce biogas and typically represent multispecies associations; (ii) installing the necessary equipment such as bioreactors, methane tanks, etc.; and (iii) dealing with the economic aspects of the whole project.

If this is a large-scale-project, a simple hirama-type network will be insufficient. Carrying out the whole project will necessitate setting up several subnetworks, each of them specializing in one of the subgoals (that will be further broken up into "sub-subgoals" by them). Each subnetwork will function as a collective analog of a partial leader dealing with a subgoal. In addition, the whole network can invite generalists that do not belong to any specialized subnetwork and promote their interaction by focusing on the intersection points between specific subgoals. Such generalists could travel around the globe, find out how biogas is produced by other teams of specialists, and update each of the subnetworks with respect to relevant issues.

10.2.2. Presence of a nervous system and a distribution system at the level of the whole organism or its analog. In human society, one of the functionally specialized subnetworks can perform the brain's functions, i.e. guide/supervise the operation of other subnetworks and that of the whole organism-like meganetwork. Subnetworks that fulfill such regulatory functions in a higher-order network were denoted as *chaperones* above. Social chaperones (intermediary structures) can perform important functions in terms of the process of joining networks into organism-like higher-order networks

10.2.3. Regulation of the general structural pattern and of the whole network's development. It is well known that social bodies, including networked ones, undergo developmental stages that are to an extent similar to those of a single organism. Organizations develop, mature, and then start "aging"; all transitions from one stage to another often involve serious crises. Optimization of the network's developmental stages including, e.g., prolonging its most efficient "adulthood stage" and staving off "aging", is an important function of regulatory internal nervous system-like subnetworks, i.e., social chaperones.

Apart from the expected promotion of scientific research, merging DNSs into larger meganetworks can have important social implications. Of significant importance for Russia and a number of other countries is establishing direct contacts between (i) governmental networks including think tanks aimed at designing the nation's political, economic, and scientific course and (ii) spontaneously or intentionally designed grassroots networks. If both kinds of networks become subnetworks within the overarching networked organism, chaperone networks will familiarize the people at large with ideological concepts and political decisions adopted by the government and also incentivize their active involvement in carrying out these decisions.

10.3. Complex hierarchy-network scenario. At the beginning of this work, it was emphasized that hierarchies are to be contrasted with decentralized networks. Nevertheless, it may be feasible to establish complex structures in which hierarchical and network principles coexist and are implemented at different organizational levels. In an analogy to the social structures of insects, e.g., ants where "worker teams" (clans) with "team leaders" form a part of higher-order decentralized network structures, it is conceivable that creative decentralized teams will include small hierarchical subteams; their leaders with experts assisting them will horizontally interact, and this interactivity will also involve non-specialized network members that may be more numerous than the specialists in the temporarily hierarchical working teams. These small teams can form a part of *circles* that are typical of the holacracy organizational pattern (see Subsection 3.3). To re-emphasize, the network structure in the holacracy system is combined with the hierarchical pattern because each circle is tasked with a specific job by, and accountable to, a broader circle, in terms of the holacracy business model.

Section eleven. NETWORK IDEOLOGY

The present work is not aimed at making detailed predictions regarding the ideology that will be promoted by currently maturing network structures including meganetworks. However, it is

DNSs’ organizational pattern per se that imposes certain constraints on the ideology that may be adopted and propagandized by such networks.

It should be noted that this discussion inevitably goes beyond the scope of the main topic of this work, the potential functions of decentralized networks with respect to the scientific community (including science-based business). This section is concerned with the mission of network structures in the general social and cultural context, although emphasis is still to be placed on its implications for scientific research and related commercial R & D activities.

11.1. Prioritizing universal human values, concerns, and goals. Irrespective of the original specific agenda of decentralized networks, their growth and conversion into large-scale meganetworks, especially according to the organismic merging scenario (subsection 10.2), promotes a multi-aspect, integral, interdisciplinary approach to the issues they deal with. In contrast, hierarchies including scientific or commercial bureaucracies tend to narrow down their focus by subdividing any issue of interest into smaller parts and concentrating on only one of them. It should be re-emphasized that many scientists that form decentralized networks exemplified by enthusiastic microbiologists (Subsection 3.1) are characterized by a broad scope of expertise and a generalizing thinking stile, which encourages them to pay attention to the philosophical implications of their research and to its importance in terms of general scientific concepts and worldview issues.

Therefore, spontaneously or purposefully established decentralized network structures may originally deal with any agenda, from promoting Mars exploration to helping stray dogs. Nonetheless, the aforementioned networks’ propensity to consider any issue from an integral multi-aspect perspective gradually causes networks to enlarge their focus so as to address an increasingly broad topic. In a similar fashion, local excitation within a brain area tends to spread to other neural networks in the brain. Eventually, most DNSs tend to converge on a universal subject such as *The World’s Future: Its Optimum Scenarios and How to Make them Possible.*

Given such a generalist thinking style of DNSs, some of them and especially their unions such as meganetworks should be capable of carrying out an important global mission. *They should be able to efficiently promote universal human values and goals.* This mission is directly linked with a cardinal ethical and political dilemma that is based on the ambivalence of human nature. Humankind can be considered from two different perspectives.

1. Undoubtedly, humankind is one single coherent entity that should focus on global issues and goals exemplified by protecting nature, controlling the coronavirus epidemic, improving the international traffic law, and others. These matters are of concern to everybody, regardless of their nation, region, or religion.
2. Nevertheless, humankind is composed of a number of self-contained and frequently conflicting ethnic, regional, cultural, and religious systems.

There were historical periods in which one of these two aspects obviously came to the forefront. The former aspect will of necessity prevail in the future if humankind finally gets in touch with extra-terrestrial civilizations.

Different types of social structures tend to prefer different perspectives on humankind. Hierarchies, especially those belonging to the state apparatus, successfully promote national unity ideologies, strengthen a nation’s state machinery and its defense system, and support the national economic and financial system (Glaziev, 2015). In contrast, decentralized networks are capable of defending global human interests in the present-day polarized, conflict-ridden world.

The objection can be raised that by far not all currently existing network structures are ready to advocate general humankind's interests despite the barriers that divide humankind. Actually, some networks may divide rather than reunite human beings if their members identify with a specific ethnicity, religion, or social class. They are typified by some of the fraternities that exist in various diasporas. More extreme examples are to be found among the dark networks of drug dealers, gangsters, or terrorists.

Therefore, a *conditio sine qua non* for joining DNSs into meganetworks is diminishing the importance of original ethnic/religious/class/parochial goals of each DNS if it is to form a functional organ of a more global network organism. A discord/conflict in terms of goals to be achieved does much harm to the meganetwork's organism. In similar fashion, the human organism is endangered by a conflict, say, between the liver and the heart. Of paramount importance for a meganetwork's well-being are chaperone networks that are analogous to the nervous system and could be metaphorically called the *brain subnetworks* of a meganetwork.

11.2. Conflict (confrontation)-mitigating potential of network ideology. Some inherent properties of decentralized networks facilitate their involvement in preventing or attenuating various kinds of social, economic, religious, political, and even military conflicts [12]. As mentioned above, an important fact is that networks tend to build bridges over barriers of all kinds to facilitate communication across them.

In contrast, many hierarchies both in biological systems and human society mark and defend the borders of their territory (in the literary or, in human society, also in the metaphoric sense). In many hierarchically organized monkey groups, the dominant male vigilantly controls the group area, whereas young individuals forming a parallel network structure tend to disregard the boundaries of this area and play with individuals from the area of another group. The hierarchy of the political system of a state makes efforts to safeguard the state's territorial integrity. The territory to be defended includes not only the geographic area but also confidential information and commercial, military, and political secrets.

Networks tend to pay less attention to territorial boundaries and to build bridges across them in order to communicate with interesting people on the other side of the boundaries (functioning as *bridging networks* according to Putnam, 2000). Important political developments were caused by links established by networks of Russian ecological activists with environmental movements outside Russia in the late 1980s. The Russians actively absorbed not only environmental information of their foreign colleagues but their political ideas as well, and proceeded to implement these ideas in their home country. Even if a network sets itself the goal of supporting a hierarchy and jointly carrying out a social/political/cultural project, the network tends, nevertheless, to establish links with "outsiders" that do not belong to this network-hierarchy tandem.

Networks are predisposed to share important secret and confidential information with competitors and enemies. Online social networks such as Facebook or MySpace face serious privacy issues. Their users supply too much information about themselves, and online networks cannot guarantee the confidentiality of private information that is of interest to advertisers or even criminals.

This network-specific feature is of relevance to networks' conflict-mitigating potential. If conflicting agents, e.g., business competitors, form a part of a single network, this causes them to

[12] In similar fashion, DNSs can help make peace within the scientific community during any kinds of fierce academic debates

develop a new identity and to engage in cooperative rather than hostile interaction, even the network has a relatively narrow agenda like controlling the coronavirus. The formal leader of the largely decentralized Biopolitics International Organization Agni Vlavianos-Arvanitis (2003) suggested biodiversity (bios) conservation as an agenda for promoting communication and collaboration among otherwise hostile states, nations, or religious movements. Global DCNs can prevent or stop military conflicts and mitigate potentially dangerous situations, performing the role of global arbiters. Making peace in the conflict-ridden areas of the planet could be the main goal of DCNs that should incorporate authoritative representatives of all conflicting parties in their organism ("mycelium"[13]).

However, not all network structures produce conflict-mitigating effects. Under certain conditions, networks may cause their own conflicts. Ignoring the boundaries of other types of structures, such as hierarchies, some networks, nonetheless, have their own nongeographic borders. They separate network members from outsiders. Such sufficiently strong borders were originally characteristic of many Israeli *kibbutzim* with an egalitarian internal structure. The presence of network—network boundaries can potentially result in conflicts, which requires the involvement of internetwork mediators. This role is one of the functions of chaperones (see above).

11.3. Interreligous aspect of network ideology. This aspect of the global ideology of decentralized networks is logically related to their conflict-mitigating potential. Even though some DNSs form under the auspices of a specific church or religious movement and, therefore, are devoted to Orthodox Christianity, Shiite Islam, Judaism, etc., they still are structurally predisposed to spread and communicate their matrix across all kinds of barriers. Therefore, they tend to overcome interreligious boundaries and develop into overarching networks that promote communication and creative collaboration between people belonging to different religions as well as between believers and atheists, clergy members and various representatives of mundane professions.

11.4. Spiritual aspect of network ideology. Irrespective of the religious, mundane, scientific, even militantly atheistic attitudes and agendas of specific DNSs[14], they, and the more so, the meganetworks into which they can ultimately merge, inevitably have to deal with spiritual matters. In terms of social psychology, human groups tend to develop a collective identity — the "we" feeling. This trend is particularly prominent in structures that foster cooperation and are not dominated by a single boss. In this respect, networks as superindividual bodies are to an extent comparable to immaterial mystical agents (spirits, deities, elements) whose existence is acknowledged by many religions. A network structure that is set up in order to attain humanitarian, charitable, democratic, environmental, or other noble goals, is analogous to the Rose of the World described by the Russian mystical thinker Daniel Andreev. According to the book entitled *The Rose of the World*, the new social structure suggested by him is to be a positive suprastate-level cultural and political movement. In order to establish it in human society, it is necessary "to fuse the most committed, creative, energetic, and gifted of its members into a

[13] I emphasize herewith the analogy between a mycelium, the filamentous body of a fungus, and such network structures that can make good use of the rhizome paradigm whose biological prototype is implemented by fungal mycelium

[14] An atheistic attitude is taken by a virtual network structure that is called *Ethnogenesis* (2020) and aims to become a global body and to form a new network-based ethnicity.

nucleus characterized by an atmosphere of unflagging spiritual creativity, active love, and purity“ (Andreev, 1997[1959]).

The journalistic articles of the prominent Russian scientist (microbiologist) Sergey N. Vinogradsky ([2013]) that deal with socialist communes emphasize that “only an idea that is not of this world that has subjugateds individual feelings and will… can fuse human souls into one entity, depriving them of any selfish cravings”.

Modern network structures that pursue noble goals also evoke the concept of the “City of God” (Civitas Dei) suggested in by Saint Augustine, one of the Fathers of the Church, who contrasted it with Civitas Terrestre, the terrestrial city that is dominated by the political system.

It is not amazing, therefore, that spiritual ideas as long as they are based on interreligious tolerance can underly the ideological matrix of decentralized networks. Recently, some proponents of Christian socialism such as Somin (2015) highlighted the role of a religious matrix in implementing the communality principle (*Sobornost')* that implies everybody’s involvement in making all major and minor decisions in the Commune. The Commune predominantly represents a DNS, although superimposed upon it is a hierarchical structure that includes the President, the Spiritual Guide, and the Labor Ministry, according to Somin’s social project

A religious believer is ready to realize that one can engage in creative work and do good, together with the whole collective, even without any hierarchy. Believers do not need any mundane hierarchy because they have only one leader, the Allmighty. Therefore, any hierarchy on Earth is arbitrary and temporary.

At this point, the *network matrix* concept is to be revisited. To reiterate, it is a network-cementing complex of ideological principles, values, behavioral norms, and, importantly, implicit knowledge such as software-developing techniques in IT specialists’ networks that only exists at the level of the whole network and is not completely available to any individual network member. A curious point is that the matrix may behave like an impersonal quasi-leader in a decentralized network where egalitarian cooperative interactions prevail over dominance-submission relationships. Like an army commander, the matrix can coerce network members into, e.g., wearing a special uniform. This situation seems paradoxical because a nonhierarchical network structure may actually have an invisible phantom leader. In similar fashion, physicists distinguish between a real image appearing where light rays converge in a system of lenses and mirrors and a *virtual image* where the continuations of actually divergent rays intersect.

11.5. Altruistic and quasi-socialist aspect of network ideology. As networks grow and merge, they tend to increasingly manifest an important feature that is beneficial for these networks as well as for the whole society. This feature sets them apart from both hierarchies and competition-based (quasi-)market structures. In terms of driving forces that make people form networks and work for them, *altruistic motivation tends to become more important than selfish incentives*. This is the reason why interactions among network members tend to be predominantly based on trust, loyalty, and a feeling of belonging (on social capital). The development of altruistic motivation in maturing networks may be additionally promoted by spiritual ideas and religious views.

During the course of their development, networks, including those in the realms of business and scientific research, start building up a *quasi-socialist system* that has its special ideological principles. This fascinating trend manifests itself regardless of the originally pragmatic, purely capitalist goals pursued by those who set up new DNSs. For instance, establishing networked “strategic alliances” among capitalist enterprises often implies that some of their resources become accessible for all members of the alliance, and this does not involve any lease or purchase-sale agreement. Not only material resources but, importantly, *information* in the modern digital world can be shared and collectively used within a network structure. Jobs and responsibilities may also be "collectivized".

The formation of an interorganizational network often involves the establishment of "ties among organizations through a member of one organization sitting on the board of another" (Borgatti & Foster, 2003, p.996), i.e., *board interlocks*. Such board interlocks are characteristic of network-dominated businesses in emerging economies, e.g., in China where interlocking firm directorates provide the foundations for small business groups that tend to be regionally fragmented (Ren et al., 2009).

A lack of centralized hierarchies within network structures enables each of their members to make important contributions to the decisions made by them and to significantly influence their collective image; this is exemplified by a large number of online networks where each individual involved can exert much influence on a whole network's behavior. This conforms with the principle of *participatory democracy* that is characteristic of socialism, as modern structural Marxists such as Robert Resch (1992) point out. Participatory democracy is contrasted with *representative democracy* which is typical of capitalism and "reflects and reproduces class inequality and exploitation by separating and delimiting those spheres that permit democratic principles from those that exclude democracy" (Resch, 1992, p. 30); such undemocratic spheres obviously include the business sphere that is dominated by corporate hierarchies and competitive market relations.

Participatory democracy within networks is associated with democratic control over means of production, which also represents an important feature of socialism (Resch, 1992) or at least a quasi-socialist system. Implementing the decentralized network organizational pattern enables enterprises to exercise democratic control over their resources, as is the case, e.g., with many American cooperatives where collective ownership of means of production implies collective control over the production process and the distribution of its results.

According to the «Member's Guide» of the Consumer Cooperative Society in Hanover, New Hampshire, that operates the Co-op Food Stores, Co-op Community Food Market, and Co-op Service Center, «Members of a cooperative support it with their patronage, participate in decision-making, and share in the profits generated by the organization's activities». «. This co-op is affiliated with a higher-order Cooperative Grocer Network that operates in compliance with the principles laid down by the International Co-operative Alliance and represents "… an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly owned and democratically controlled enterprise." (International Co-operative Alliance Statement on the Co-operative Identity; see Cooperative Grocer Network, 2014).

Modern information technology and online facilities promote quasi-socialist participatory democracy in network structures on the Internet or in real-life settings. This might be considered "electronic democracy" since (1) computer technology is user-friendly, accessible for everybody, and interactive (2) "using the technology … increases the social importance of its users; (3) applying the technology results in citizens' direct involvement in decision-making; and (4) modern electronic technology enables direct communication among a potentially infinite number of members of virtual communities (Tischenko, 2014, pp. 58-59).

Currently, such quasi-socialist and meritocratic (favoring the most qualified network members) principles are also making their way into research labs, science-based business teams, and science parks, as exemplified by the Oxford Science Park discussed in Subsection 3.3 above.

Section twelve. LEGAL MEASURES FOR PROMOTING DECENTRALIZED NETWORK STRUCTURES

The successful development and harmonious functioning of decentralized network structures in various spheres of society including the scientific community as well as their efficient interaction with hierarchical and (quasi-)market structures should be facilitated by relevant legal regulations. In many countries, exemplified by Russia, the legal status of DNSs and their inalienable rights could be stipulated in the country's Constitution. The term "network structure" should become as legally important to governmental officials as, e.g., the US terms "Limited Liability Company" or "Inc.". Such officials should also be ready to deal with unusual accounting documents presented by DNSs, as their structure is different from those of conventional hierarchical companies. For the time being, it should be noted that, e.g., in Russia, the development of integrated interregional network structures /as well as of other kinds of networks– O.A./ has not yet been supported with legal and statistical documents and lacks strategic guidelines (Kantemirova, 2014, p.9).

12.1. Establishing a Research Institute for Network Structures (RINS). This would be an unprecedented innovative measure; to the author's knowledge, there are no research centers around the globe that concentrate on networks only. However, this new institute could be to some extent similar to currently flourishing interdisciplinary centers typified by the Santa-Fe Institute. The hypothetical institute can be established in the form of a decentralized network structure that prospectively could develop into a multilevel network closely collaborating with other relevant DNSs, resulting in the formation of a meganetwork. The intellectual production of the Research Institute for Network Structures would be useful for various fields of science. In fact, the interdisciplinary *network structure* concept is applicable, apart from human society, to biological systems, technical devices, a human individual's mind, etc.; this concept also appears to have religious implications. However, it is in scientific research together with the commercial applications of its results and in the business sphere that the RINS seems to hold special promise in the current turbulent, crisis-ridden globalized world. As an interdisciplinary research center, the RINS can extrapolate organizational patterns and scenarios from one area of research to another. As pointed out above, living nature provides the developers and promoters of network structures with a number of potentially important organizational recipes, i.e. network paradigms used by diverse biological systems (Subsection 2.2). Research on chaperone networks and their promotion in present-day society could also form a part of the Institute's activities. Interestingly, an analogous research center named *the Competence Center* has recently been suggested by Dr. Vladimir Rumyantsev (oral communication) for a digital economy-based society. This center should focus on "making predictions regarding interdependent digital platforms and services and also harmonize and synchronize their operation".

12.2. Promoting networks: the potential mission of the educational system. It is imperative that network structures-related knowledge should be disseminated in present-day society. This knowledge could be efficiently spread using the whole modern educational system. Networks can be considered, from the educational viewpoint:

- In conceptual terms: students are to be familiarized with interdisciplinary concepts related to networks and belonging to diverse fields of science, ranging from mathematics to philosophy, sociology, psychology, biology, and religious studies.
- In organizational terms: network structures should be set up in the classroom, students are to be involved in forming their own networked creative teams, and teachers should establish their own DNSs (see Section 6).

For this purpose, relevant amendments should be made in national, regional, and local curricula and syllabi. Since the currently developing digital economy (DE) stimulates the spread of DNSs in the whole society, a potentially useful practical step would be establishing special *education centers and DE accelerators* promoting the work of network teams composed of DE specialists (Rumyantsev, oral communication).

12.3. Taking measures to facilitate the development of social chaperones. Chaperones were discussed in Section 9 above. To re-emphasize, such guidelines-providing and DNSs-promoting network structures should include prominent scientists, scholars, educators, and experts competent in socially and scientifically important matters; this would be in compliance with the principles of *network meritocracy*. Officially acknowledged criteria should gradually be established for selecting the members of promotive chaperone networks.

12.4. Establishing a Networks-Promoting Committee (NPC). Chaperone functions can also be performed by state-level organizations tasked with guiding and promoting DNSs. It was pointed out above that chaperones should be predominantly characterized by a decentralized network pattern. However, the term "committee" seems to imply a hierarchical (bureaucratic) rather than a decentralized structure.

In fact, this chaperone is to be closely linked with the central political system and, in similar fashion, should be at least partly hierarchical (pyramidal). This hierarchy could be headed by a president that should authoritatively represent the Committee during its interaction with the offices of the political system; in Russia, it could efficiently interact with the Constitutional Court and the Supreme Court of the Russian Federation[15]. Such interaction is of paramount importance for enacting and adopting new laws regarding the legal status of network structures, including chaperone structures themselves. Presumably, the Networks-Promoting Committee will concern itself with developing and implementing legal measures for promoting DNSs both within the scientific community and in other spheres of society, including network structures that pursue humanitarian, charitable, environmental, health care-related, and cultural goals. In addition, the NPC should develop legal tools for exposing and suppressing dark DNSs associated with corruption and crime.

Apart from its legal functions, the NPC could also facilitate useful interaction between decentralized networks and hierarchies, including bureaucracies, as well as between networks and (quasi-)market structures or between networks and networks. This interactivity requires the involvement of intermediaries (chaperones) that could be set up at the local level with the aid of the NPC. In similar fashion, the transition to DE calls for establishing special state-level regulatory institutions and tools (Rumyantsev, oral communication).

[15] Similar institutions exist in many other countries around the globe

12.5. Establishing counseling bodies for DNSs. As a supplement to the NPC, state- or private investors-sponsored counseling organizations could be set up. This would be a useful additional practical step. Such counseling bodies could differ in their specialization and size. They should aim to help network structures solve a wide variety of organizational, technical, and psychological problems that inevitably arise at all lifecycle stages of these innovative structures in various spheres of society, including scientific and business institutions. Obviously, counseling bodies can be considered a variation on the theme of social chaperones; their internal structure should preferably follow the decentralized network pattern.

12.6. Promoting grassroots network structures (networked citizens' associations). All the above bodies, including the Research Institute for Network Structures, the Networks-Promoting Committee, and counseling bodies, belong to *top-down networks:* they are to be established according to decisions directly made by the state government[16].

However, *grassroots,* or *bottom-up, decentralized networks,* to be set up by ordinary citizens, also have much social potential. Such DNSs are composed of citizens who do not enjoy any special privileges; they can defend their interests and rights only by forming networks. With rank-and-file scientists, such rights also include the right to conduct enthusiastic research in networked teams that do not belong to hierarchical institutions (real-life examples are provided in the aforementioned dissertation on history of microbiology: Kirovskaya, 2005). A short-sighted policy of the political elite would be ignoring and, the more so, suppressing grassroots networks. On the contrary, it seems that the state apparatus could significantly contribute to the development of grassroots DNSs; a challenging task would be to bridge the gap between top-down and bottom-up networks. Carrying out this task can be promoted by intermediary chaperone bodies.

It is hoped that the support of the political elite (including the state government) and the guidance provided by chaperones will enable spontaneously or purposefully established grassroots networks to acquire the status of *legal associations* under the Russian law (or a similar status elsewhere on the planet). Of significant importance are the following agendas/goals for grassroots DNSs:

- Promoting health care and defending the interests of both health care workers and patients
- Taking care of orphans, homeless people, the aged, and other socially unprotected groups of citizens
- Protecting nature and life (bios)
- Conducting interdisciplinary research, particularly if the researchers do not belong to any official bureaucratic scientific institution and work as independent free lancers
- Exercising public control over courts, police stations, prisons, etc.
- Reforming the educational system at all its stages and levels, clearing up dodgy questions exemplified by the questionable validity of the *ЕГЭ*[17] test in Russia

[16] Historical note: under Nicolas the Second (in the early 1900's), the monarchical ideology was propagandized in the working class with the aid of a partly decentralized network created on the initiative of Zubatov, an official of the Police Department of the Russian Empire.

[17] This is the so-called *Unified State Exam (ЕГЭ, Единый государственный экзамен)* that can potentially be abused by corrupt teachers and whole educational bureaucracies, unless independently controlled by educational activists' networks; similar issues might plague the educational systems in other countries with heavily bureaucratized versions of performativity culture-dominated education.

- Dealing with internal policy matters including taxation, retirement policies, and other matters of importance to rank-and-file employees.

Evidently, all these issues and problems are also to be addressed by the state government, and they can set up elite DNSs such as networked think tanks and use their recommendations. To reiterate, it is social chaperones that can mediate the dialogue between elite and grassroots DNSs, in order to jointly sort out pressing social problems and achieve important goals, including reforming the scientific community and increasing the efficiency of science-based R & D activities.

CONCLUSION

There are at least three important reasons why establishing decentralized network structures to perform the functions of research labs, business entreprises, and many other kinds of social bodies should be envisioned as a priority goal in present-day society:

- From the practical viewpoint, DNSs have the power to cope with the challenges and requirements of the modern-day turbulent dynamic world, while more conservative, thick-skinned bureaucratic hierarchies may often fail to meet them.
- From the social psychology viewpoint, DNSs promote feelings of safety and belonging with their members, enabling them to be socially protected---and convinced that their life is of significant social importance
- From the cultural viewpoint, DNSs conform with traditional communal and spiritual values and principles that are inherent to human nature and to most national cultures**.**

As far as the scientific community is concerned, the analysis of DNSs performed in this work gives grounds for the suggestion that *scientific research can be conducted much more efficiently if new options provided by innovative decentralized network structures are taken into account and sufficiently widely used in organizational terms.* The author prefers a moderately optimistic attitude towards the future of the global scientific community and its local parts including, notably, Russian or Chinese academia. Decentralized creative labs and teams of enthusiastic researchers, networked R & D centers dealing with biotechnology, nanotechnologies, pharmacy business, IT, or space exploration should enable both science and technology to flourish in the current troublesome, crisis-ridden, historical period.

The present work also demonstrates that successfully carrying out the mission of improving the organization of scientific research institutions is only possible if, apart from modernizing scientific institutions per se, the whole social and cultural system is adequately reformed; new network society-related values are to become socially accepted, and the young generation of scientists/scholars should be subtly indoctrinated with them, which could be an important aspect of the functions of chaperone bodies. The emergent network ideology prioritizes universal human goals and values, despite the political, cultural, and religious barriers that divide the humankind body into conflicting parts. A prerequisite for the spread of useful network structures with noble missions in the present-day world is the development of a system of spiritual values that is to be adopted by scientists, scholars, entrepreneurs (regardless of their specialization), and the people at large. I re-emphasize that this new value system is expected to promote altruistic behavior and quasi-socialist principles inside network structures even if they arise in a capitalist environment and are originally based on pragmatic motivation.

The author envisages this work, although it may seem partly chaotic, as an attempt to sum up many of the concepts and research results concerning network structures that have been in the focus of the author's attention during the whole course of the long scientific career.

Even though this work may be not quite logically consistent, I hope from my heart, nevertheless, that attentive readers will find, in its text, some ideas that are in unison with their own views and, moreover, accept some of the recommendations regarding the promotion of scientific research by means of decentralized network structures.

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