Comparing Social and Biological Multilevel Network Structures (Exemplified by Environmental Movements and by Natural Ecosystems)

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The present work deals with decentralized cooperative network structures that are contrasted with hierarchies and competition-based (quasi-)market structures. Decentralized network structures have significant potential as an organizational pattern to be used by creative teams in various spheres of society. In order to exert sufficient social (political, economic) influence and to carry out large-scale projects exemplified by those dealing with the environment, network structures should combine to form decentralized "supernetworks". A similar challenge of joining networks into higher-order structures is met by living nature: population-level network structures of living organisms combine to form coherent local associations (communities), whose alliances are known as ecosystems. In this work, several possible scenarios of combining networks are set forth, including (i) the contract-based; (ii) the organismic; and (iii) the hierarchy–network scenario. In conclusion, a pilot project of setting up a large-scale environmental network dealing with protecting regional plant resources is outlined.

Keywords: Decentralized Network Structures, Hierarchies, Biological Paradigms, Environmental Movements

1 Introduction

According to their general meaning, *network structures* are defined as any systems of elements (vertices, nodes) connected by links (edges) [1]. This general definition is widely accepted and applied to diverse kinds of systems [1-5] ranging from star conglomerations to crystals to clusters of elementary particles to technical devices.

However, there is also a more specific definition of a network structure that has been in use from the 1980s on, predominantly in the social sciences [6-13] and in the field of information technology [14]. In accordance with this definition, not all systems composed of elements connected by links are to be called *network structures*.

As per this meaning, a network should lack a central element (leader, pacemaker), i.e., represent a *decentralized* structure; its behavior should result from complex interaction among its nodes that may include temporary, partial leaders with a limited influence on the network's activities. The WorldWideWeb is predominantly based on this organizational principle. In this work, the term *network structure* is used in the specific sense unless otherwise stipulated.

Network structures are multi-component cooperative systems. Self-organization and efficient adaptation to environmental factors, also denoted as “collective self-education” (that is particularly characteristic of neuronal networks and their analogs), are among the typical features of nonhierarchical networks that lack a central controlling agency. Therefore, network structures are on the agenda of such recently developed areas of research as cybernetics, systems theory, and especially synergetics.

The present work concentrates on network structures in *human society* that are compared to those in various *biological systems*. Decentralized network structures in human society may represent intentionally established creative teams, e.g., think tanks[1] 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 [15]. 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* [16] that brought together people suffering from chronic diseases 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 the people involved. The founder of the AntEra Association Alexander Krel’ emphasized that the aid to be provided should not be confined to medical treatment. It should positively influence all aspects of the patients’ lifestyle in social, economic, cultural, and spiritual terms [16]. 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, shared attitudes towards the rest of society, and, to an extent, the same stigma. Spontaneous networks arise in the economic sphere unde the influence of virtual currencies and the blockchain system.

In this work, decentralized network structures are discussed in connection with current *environmental problems and issues*. Decentralized network organization patterns can be used for establishing large-scale (national, regional, or global) bodies involving environmental activists as well as competent scientists and scholars. It is present-day environmental challenges that fuel interest in setting up network structures and combining them, in a decentralized fashion, for the purpose of coping with the global ecological climacteric. Such combined networks also promote global cooperation among people despite political barriers and conflicts and, therefore, ameliorate the global political atmosphere.

Importantly, flat decentralized structures (revealing much similarity to the leaderless schools of many fish species in organizational terms), have been already established in

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[1] Think tanks performs research and advocacy concerning topics such as social policy, political strategy, economics, and technology

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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)* that has been in operation in Russia and some other republics of the former Soviet Union. The SEU has succeeded in bringing together the "people who are ready to work for our common future" [17]. Since its institution in December 1988, the Union has lacked a "vertical power structure". Each SEU member is encouraged to take action independently, in compliance with the SEU Statutes. Even though the SEU structure includes the Chairpersons' Council and the Head Office, these bodies do not control the SEU members, they merely assist them in the activities in which they decide to engage and provide them with detailed relevant information [17].

2 HIRAMA Model

It is in the environmental context that I briefly describe herein a type of network structures that can potentially be scaled up to form the basis of an efficient global networked body. This structure is referred to as the *HIRAMA (High-Intensity Research and Management Association)* [15, 18, 19]. This is a creative team that is set up for tackling an interdisciplinary project as exemplified by *Assessment of the State of Plant Ecosystems.* This general project is broken down into more specific subprojects. For instance, the aforementioned issue can be considered to include 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. Only one person, the *partial subproject leader*, is attached to a particular subproject. The person collects ideas on this subproject [15, 18, 19]. 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. "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… leisure activities, thus contributing to the development of informal loyal relationships among members" [15]. Additional leaders, e.g., an *organizational leader,* are useful when a HIRAMA is organizing its work and legalizing its status in compliance with the laws of the respective country.

3 Rundown on Decentralized Network Structures in Biological Systems

A large number of diverse biological systems are decentralized; cooperation among their components dominates over competition. For instance, “microbial colonies or biofilms consist of a multitude of cells, and a lack of a single central controlling unit does not prevent the effective coordination of social behavior” [15].

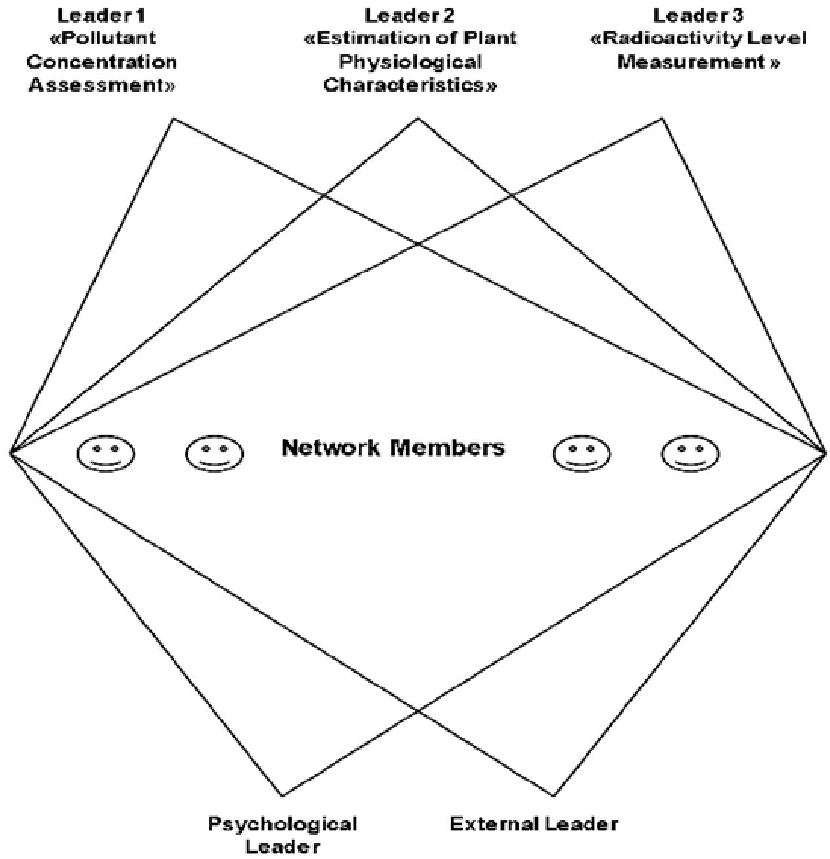

Fig. 1. HIRAMA-type network structure applied to the assessment of the state of plant resources (see text for explanations)

Decentralized network structures in biological systems are based on a number of different organizational scenarios. Many of them are of interest not only to biologists

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but also to social scientists and social engineers because they can be creatively used to set up human network structures. The following biological network structures, or network paradigms [15, 18, 19], seem to hold special promise:

- Microbial biofilms (the cellular paradigm)
- Cnidarian colonies (the modular paradigm)
- Neural networks (the neuronal paradigm)
- Leaderless fish schools (the equipotential paradigm)
- Societies of ants, bees, or termites (the eusocial paradigm)
- Fungal mycelia and plant rhizomes (the rhizome paradigm)
- Egalitarian monkey and ape troops with mitigated hierarchies (the egalitarian paradigm).

These network organization paradigms are briefly characterized in the Table.

For instance, the following principles underlie the egalitarian organization of the troops of chimpanzees, bonobos, and some capuchins [20-22]:

- Securing individual freedoms including the freedom of choice;
- Partial hierarchization of the structure involving the respect paid to high-ranking troop members; however, no single individual is allowed to exert permanent control over the whole structure;
- Loose ties between troop members typified by those in the fission-fusion groups of chimpanzees

Interestingly, many primitive hunter-gatherer bands used similar organizational principles. This network paradigm seems potentially applicable to networked labs emphasizing independent individual creativity and the patronizing role of high-ranking network members. Without equating the organization of ape troops and of human social structures, it should be noted that, e.g., networked teams of research scientists are characterized by the following analogous features:

- Respect for individual freedoms. Each of the researchers is allowed to deal with their own area of research and develop their own concepts; this freedom is only limited by temporary commitments related to joint projects, publications, and conferences.
- Partial hierarchization of the structure resulting from acknowledging the achievements and scientific titles/degrees of network structure members (in an analogy to the high-ranking "silverback" males of gorilla troops); however, no single member can dominate the whole networked team.
- Loose ties between network members, their right to join the network or quit it [15].

Analogous "ape-style" principles can be implemented in small-size human networks that only contain a limited number of individuals, as exemplified by egalitarian groups that are formed by leading businesspeople, prominent scientists/scholars, or politicians and aim to resolve important economic, scientific, or political issues.

It should be noted that such "ape-style" loose networked teams seem to meet all prerequisites for creative think tanks that can deal with complex environmental issues and develop long-term ecological strategies. Nonetheless, the loose ties that are characteristic of such networks may cause serious problems if the network is aimed at carrying out a project that requires long-term stability of the network structure.

Table . Network paradigms in the plant world and their application to human society (according to the author's work: [19], modified and supplemented with new data)

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)
Equipotential	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,, intrapopulation plant groups	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, plant communities and ecosystems	Working teams with temporary leaders interact with non-specialized network members within higher-order networks, e.g., small environmental teams combine

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			to deal with large-scale projects
Neural	Neural networks are capable of collective information processing and decision-making.	Animal or human nervous systems and their analogs	Working teams with temporary leaders interact with non-specialized network members
Egalitarian	Based on individual freedoms; respect for high-ranking members; and l*oose* 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

4 Challenge of Establishing Large-Scale Networks. Polycentric System Concept.

An urgent task in the present-day developing information society with 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, political, and environmental projects, for stabilizing the political system and motivating people 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 the hierarchical structures of the political system.

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 originally set up by 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 put forward by Vincent and Elionor Ostrom [23-25]. In terms of this concept, political, social, and environmental decisions are made during negotiations that involves 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 [25] and coral cay protection in Palau (Oceania) [26]. "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" [15].

5 Scenarios of Joining Network Structures in Living Nature and their Application in Human Society

Living nature has been developing efficient scenarios of joining network structures in various biological systems during the course of evolution. Using these scenarios is of much potential use in terms of promoting network-network interactivity to the point of establishing higher-order "supernetworks". There are micro-, meso-, and macrolevel structures in human society; likewise, 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 predominantly operate in a harmonious way, facing 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 "supernetworks" in both situations is based on several typical scenarios. They can potentially be creatively used for achieving the goal of promoting network—network interations in human society. To reiterate, the resulting "supernetworks" 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, and (iii) building up sufficient resistance to giant industrial companies (if the small networks are SMEs that cannot survive competition with industrial monopolists on their own).

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5.1 Contract-based Scenario

According to this scenario, two or more network structures, whether in living nature or in human society, make contracts to form temporary project-oriented networked alliances without losing their organizational independence. As mentioned above, netwoek 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 where an analog of the contract-based scenario works at the level of interactions among individuals that 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 [27]. 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 (see above). 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 with different HIRAMAs. The external leaders that are "on the staff" of each HIRAMA start negotiations that also involve creative leaders specializing in the aforementioned goal. This results in the formation of a temporary creative inter-HIRAMA alliance that may be based on an official contract which does not restrict the autonomy of the network structures (HIRAMAs) involved.

5.2 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 "supernetwork".

Organizational scenarios aimed at establishing long-lived multilevel networks should envisage them as *analogs of living organisms.* 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 [28]. Some of his ideas are reformulated below in order to extrapolate them to human social networks:

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 organs (the heart, the lungs, the kidneys, etc.) of a biological organism. Therefore, each network that forms a part of this organism-like large network loses its independence.

Organismic properties are characteristic of many structures denoted as stable networks in the literature [27]. They include 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 [7], 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 (a HIRAMiade). 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* (see example in Section 2 above) were to become a second-order network (a HIRAMIade), then each of the three subproblems in the list would be addressed by a self-contained HIRAMA This subproblem, e.g., Assessing the Pollutant Concentration and the Radioactive Background, would be further subdivided into narrower "sub-subproblems" in which specific creative partial leaders would specialize. In addition, each small HIRAMA would include its own psychological and external leaders.

Presence of a nervous system and a distribution system at the level of the whole organism or its analog. The specialized organs of an organism-like "supernetwork" should, according to [28], include those responsible (i) for monitoring and regulating the behavior of whole network, i.e., an analog of the nervous system of a biological organism and (ii) for distributing resources to various parts of the network, i.e., an analog of the circulation system.

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 network. Subnetworks that fulfill such regulatory functions in a higher-order network were denoted as *chaperones* in the author's previous works [29, 30].

The term chaperone was first suggested at a biological conference in Copenhagen in 1987 and shortly thereafter mentioned in an article published in *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" [31].

Many molecular biological systems contain biological chaperones that represent molecules regulating the assembly, folding, and functioning of other biological molecule.

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Social chaperones (intermediary structures) are construed herein as analogs of molecular biological chaperones. They can perform a number of important functions in terms of the process of joining networks into organism-like higher-order networks , including the following

- Promoting the development and dissemination of decentralized network structures in all spheres of society in which they are useful. With respect to organism-like networks, this implies that functionally specialized subnetworks should be established wherever (whenever) there is a function to be fulfilled at the level of a whole "supernetwork".
- Familiarizing network structure developers in various spheres of society with the whole spectrum of different organizational types of networks. Importantly, network structures can be based on a wide variety of organizational scenarios (see Table above). Biology is an important mine of information in this respect, and different functional subnetworks, like different organs in the organism, should prefer different structural patterns
- 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. Chaperones also may ameliorate interactions between several structures of the same type, for instance, between several network structures, including subnetworks in an organism-like network. This chaperone's job resembles the regulatory function of several systems in the human organism, notably the nervous, endocrine, and immune system, in promoting cooperation between different organs and mitigating any intraorganismic "communication problems"

Regulation of the general structural pattern and of the whole network's development. This organismic feature that was also singled out by Beklemishev [28] can be implemented in the "supernetwork" if the aforementioned chaperones provide guidelines to the network with respect to its structure and life-cycle. 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, maturate, 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 social chaperones. Importantly, their subtle influence should not transform into coercion because dominance-submission relationships are not characteristic of networks that, by definition, represent decentralized, largely horizontal, structures. This subtle guidance is expected to become particularly prominent if the interacting subnetworks of the organism-like networked body belong to different social strata and levels.

Of significant importance to Russia and a number of other countries is establishing direct contacts between governmental networks (including think tanks developing the nation's political and economic course) and spontaneous or intentionally designed grassroots networks. If both kinds of networks become subnetworks within an overarching networked organism, chaperone networks will (i) familiarize the people at large with ideological concepts and political decisions adopted by the government and (ii) incentivize their active involvement in carrying out these decisions.

5.3 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. An example is provided by biological systems.

The social structures of insects, e.g., ants, include “worker teams” (clans) with “team leaders” that are tasked with jobs like digging the ground or collecting aphid honeydew [32-35]. Hierarchical relationships are also established between different functional groups in an ant colony: foragers and scouts have a higher social rank and more prestige than those who nurture the larvae and take care of the queen. However, despite the “team leader” function and the rank differences, even the most prestigious individuals behave as only partial leaders within a higher-order network structure (a column or a pleiad, the terms used by Zakharov [35]) that combines a large number of “worker teams”.

Another feature of many social structures of insects is that specialized worker teams with their leaders co-exist with a pool of non-specialized network members that are potentially ready to do any kind of job. For instance, non-specialized ants are mobilized whenever an anthill is attacked by enemies. A similar principle of combining teams of specialists with a pool of generalists supporting them is feasible in human network structures.

The hierarchy-network scenario can potentially be used for setting up efficient multilevel teams of environmental activists. Such 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 hierarchical working teams. Many hobby clubs employ similar organizational principles.

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). Each hierarchical team will form a part of a higher-order horizontal network that has the potential to carry out large-scale projects requiring costly equipment for assessing such environmental characteristics as the concentrations of toxicants in the water, soil, and air and the population dynamics of characteristic biological species.

6 Pilot Project Based on Combining Several Network Organization Scenarios: A Creative Multilevel Network Structure Tasked with *Plant Resource Protection*

In conclusion, a brief pilot project is set forth hereinbelow. Modifying a network-style organizational project concerned with rehabilitative medicine and set forth in the

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work [19], I suggest a complex multi-level structure to provide organizational foundations for a large-scale environmental organization. Its main goal should be Environmental Protection with Special Attention to Regional Plant Resources (for instance, the target area may be the region around Saint-Petersburg). It is based on the HIRAMA model (see above).

Apart from the HIRAMA as such, the organizational project in question should also use the *neuronal network* as a model The nodes of the neuronal network form several different layers that specialize in different stages of handling information and making decisions, from acquiring information (the input layer) via its collective processing (the hidden layer(s)) to making the final decision (the output layer) (Fig. 2).

The pilot network structure to be used for attaining the aforementioned goal should include three modules that deal with the following subgoals:

- Module 1. Evaluation of the State of Plant Resources
- Module 2. Development of the Conceptual Strategy for Protecting Plant Resources
- Module 3. Elaboration of Practical Measures for Carrying Out the Conceptual Strategy

Each module combines two different scenarios: (i) a neuronal network and (ii) a multi-level HIRAMA. This can be illustrated using Module 1 (Evaluation of the State of Plant Resources). All members of this module of the network form three different layers:

- *Input layer*: collecting data on photosynthesis intensity, pollutant concentrations, radioactivity levels, etc.
- *Hidden layer*: summing up the information obtained and putting together daft documents concerning the flora state
- *Output layer*: preparing final reports that contain the decisions made by the whole-module.

The members of the input and hidden layers address all subprojects of Module 1.

However, the members of the output layer specialize in one of the following subprojects:

- Partial leader 1: Measuring the Intensity of Plant Photosynthesis and Light and Dark Respiration
- Partial leader 2: Determining Pollutant Concentrations.
- Partial leader 3: Estimating the Radioactivity Background Level

These leaders collect data from all hidden layer members. Each of these partial output-layer leaders supplies the input and the hidden layers with the feedback to be used for error correction (in compliance with the principles of Hopfield recurrent networks).

Module 1 also contains a psychological leader and also an external leader who is tasked with reporting the final results during the meeting of the external leaders of all the Modules. Likewise, Module 2 and Module 3 are internally structured as neuronal 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. The projects they carry out represent subprojects within the framework of the more general project (Environmental Protection with Special Attention to Regional Plant Resources) addressed by the whole second order HIRAMA.

The second order HIRAMA 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 government to environmental 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 with which the second-order HIRAMA has to interact.

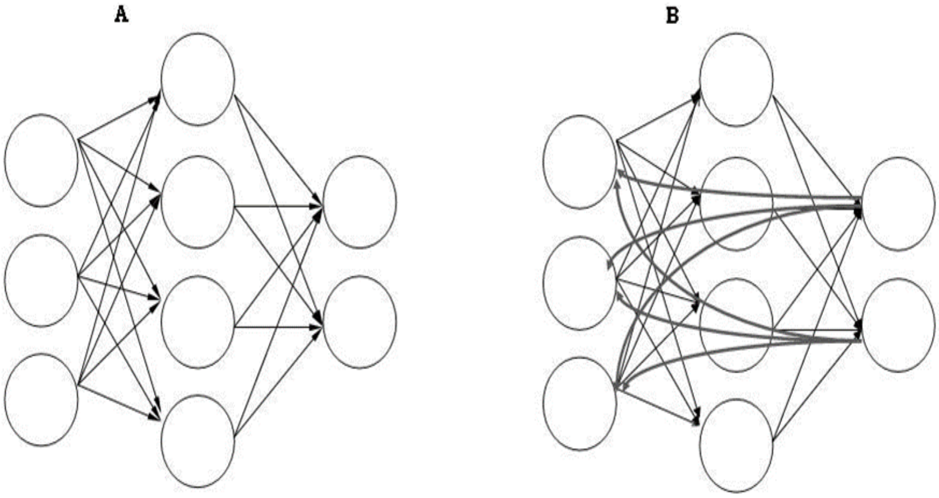

Fig. 2. Neuronal networks combine consecutive (input → hidden layer(s) → output) and parallel information processing. (A) Perceptron; (B) Recurrent neural network with additional feedback links running from the output to the input layer (according to the author's work: [15])

The second order HIRAMA may include additional members with various professional backgrounds ranging from politicians and business people to ordinary citizens like a Russian janitor called Vasily. They are not involved in the activities of any of the Modules; nevertheless, they can provide their critique concerning the whole project.

To sum up, the main goal of the present work was the application of the principles of decentralized network structures for establishing networked teams specializing in environmental conservation exemplified by plant resource protection, which is of paramount importance for the survival of humankind. At the same time, environmental networks are to carry out the additional mission of promoting cooperation and mitigating conflicts around the globe. While designing network structures and combining them

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to form large-scale networked bodies, account should be taken of the network organization paradigms that have been successfully tested by living nature during the whole course of biological evolution

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