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Networks as a unifying pattern of life involving different processes at different levels – An interview with Fritjof Capra

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We all need to better understand networks. Their importance is growing as a form of organization whose efficiency has been enhanced by information technology. The body of knowledge that deals with them has mushroomed in the last ten years or so. The internet – network of networks – is now a significant part of the life of hundreds of millions of people. The metaphor is part of our everyday vocabulary. And still, it is used in so many cases, to describe, refer or allude to so many situations that its "polysemy," as Michel Callon puts it, can be easily confusing. Networks and complexity have so many things in common that we tend to let specialists deal with the issue, understand it, analyze it, use it.

This is wrong. Networks should not be the sole territory of brainy scientists. We should all learn about them, take advantage of the available knowledge about what they are, where they appear and how they operate.

Manuel Castells' trilogy on "The Information Age" has played a major role in this rising awareness. The fruit of decades of research is presented in such an accessible form that laymen and women can find there most of what they need to understand about the network society. But once you become aware of networks, you find them in a lot of other places, at other levels. The meme viral effect is contagious. You want to know more.

That's what brought me to Fritjof Capra's work on the subject. Manuel Castells said I should pursue my quest to better understand networks in reading "The Web of Life and The Hidden Connections." That's how I learned Capra lives in Berkeley, very close to me. We even shop in the same supermarket. It was a wonderful adventure to find again the author of the fascinating Tao of Physics. That's how I read the books, which show the importance of networks at the biological, cognitive, and social levels of life.

How not to be impressed by what he calls in the first sentence of his first answer to this interview "a unified scientific view of life" based on our knowledge of evolution. "In my view," he says, "there is a unifying set of patterns of organization that goes through all life, at all levels and in all its manifestations."

Isn't that a worrisome open door to another unified theory of everything or the outline of one?

This is exactly what I had in mind when we started the interview. And Capra's answer came flat: "There is a fundamental error in this view. Even though there is a unified basic pattern of life, and we can be more precise and say that this pattern is a network pattern, these networks are not structures – at least most of them – they are functional networks." The term can be used as a metaphor, it is not as a paradigm.

Recognizing the specificity of each "level" he explains what distinguishes them. At the social level, in particular, he clarifies the importance of meaning, values and power (and therefore conflicts), key elements in extending his approach to societies. This, he says, is the product of his many discussions with Castells, and a bridge between the two bodies of work. Interestingly enough, Capra then moves a step further than in his books when he states that "The core of my social agenda is sustainability."

In this conversation, Fritjof Capra, while staying totally coherent with the scientific studies on which he bases his works, transmits many of the core elements of his thinking about networks in terms that the lay audience can understand easily.

The interviews were conducted and recorded at my home. Fritjof was kind enough to revise the text twice, just after we spoke, in 2003, and in October before the publication in the IJoC.

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Interview

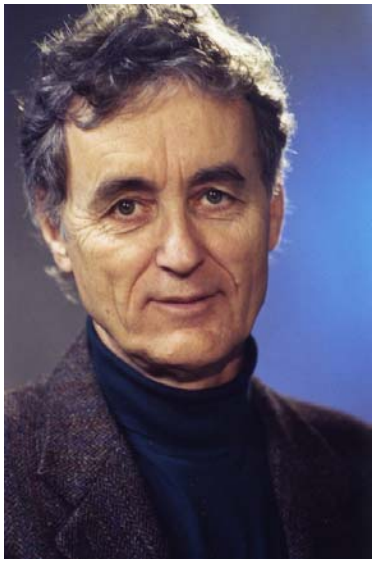

Figure 1: Fritjof Capra

A unified theory of life?

FC — What I am trying to do is to present a unified scientific view of life; that is, a view integrating life's biological, cognitive, and social dimensions. I have had many discussions with social

scientists, cognitive scientists, physicists and biologist who question that task, who said that this would not be possible. They ask, why do I believe that I can do that? My belief is based largely on our knowledge of evolution. When you study evolution, you see that there was, first of all, evolution before the appearance of life, there was a molecular type of evolution where structures of greater and greater complexity evolved out of simple molecules. Biochemist who study that have made tremendous progress in understanding that process of molecular evolution. Then we had the appearance of the first cell which was a bacterium. Bacteria evolved for about 2 billion years and in doing so invented, if you want to use the term, or created most of the life processes that we know today. Biochemical processes like fermentation, oxygen breathing, photosynthesis, also rapid motion, were developed by bacteria in evolution. And what happened then was that bacteria combined with one another to produce larger cells - the so-called eukaryotic cells, which have a nucleus, chromosomes, organelles, and so on. This symbiosis that led to new forms is called symbiogenesis.

Symbiogenesis continued throughout the evolution of life, so that today we can see even in the largest organisms, like ourselves, that many of our structures actually come from bacteria. So, not only do we have bacteria living inside us, as all larger organisms do, but we also have incorporated part of the mechanisms of bacteria and part of their DNA into our own DNA. This was confirmed dramatically by the Human Genome Project. They discovered a lot of bacterial DNA in the human DNA. So, when you study evolution from this point of view, you see that nature did not create large structures from nothing, but used the same patterns over and over again, the same processes in different combinations. This is now well accepted. Steven Jay Gould has written voluminously about it. So, in my view, there is a unifying set of patterns of organization that goes through all life, at all levels and in all its manifestations.

Now, this is not something that I can prove, but this is my credo and my starting point. And it comes from what I learned from evolutionary theories. I think what most people have a problem with is that they believe erroneously that I am proposing a certain theory, or the outlines of a certain theory, and that I believe, once this theory has been completed, you can then apply it to all kinds of phenomena. To put it in an exaggerated way, you would have a master equation and you could feed the US economy into this equation and get some answers; and you'd put in cancer and get some answers, social justice, and so on. All these manifestations of living systems would be governed by the same master equation.

There is a fundamental error in this view. Even though there is a unified basic pattern of life, and we can be more precise and say that this pattern is a network pattern, these networks are not structures – at least most of them – they are functional networks. There are web-like relationships between certain life processes. And the pattern of these relationships, the actual configuration of these relationships — patterns like the network, feedback loops, or the process of emergence — can be observed throughout life. But the processes that are interconnected by these patterns are different at different levels and in different domains. So, for example, when I study a cell, I can say "a cell is a molecular network," it's called the metabolic network. The genetic network is part of that. The processes that are interconnected in the network are biochemical processes. If I don't know my biochemistry, I won't be able to explain anything that happens within a cell. Although I can observe a network pattern, I cannot really understand if I don't know what an enzyme is, and how it interconnects various processes as a catalyst. Similarly, in a human community the network pattern is a pattern of communications. It interconnects individual processes of communication that create ideas, information and meaning. So, we need to address the

question of meaning in terms of social science, political science, anthropology, philosophy, history and so on. The social sciences and the humanities have to be drawn in to deal with the level of meaning. Only then will we really understand what's going on in a community. We can draw diagrams, and people do that. They say, person A has 4 connections in a company and person B has 6 connections; they draw little stick figures and show how they are connected to other stick figures. But to me, it does not mean much because they don't deal with the dimensions of meaning, of culture, of consciousness. So, to come back to the original issue, a unified theory is unified only through the patterns of organization, but it's not a complete theory. I don't even call it a theory, I call it a unified view of life, mind and society. And it's the pattern of organization, the formal aspect, that interconnects the different domains, but the content and the nature of the processes are different in each domain.

Four perspectives on life

FP — In your book you explain very clearly the three dimensions of matter, process and form…

FC — Right, and meaning is the fourth dimension in social systems. Let me just say that extending the theme of the three dimensions to the social domain has been a major problem for me, because in my original framework I used the terms structure, pattern and process. I adopted the language from biology, and then I found out that social scientists also talk about structure, but they mean something very different. What they mean is more like what I call pattern. This created a lot of confusion for me, and finally I changed my terms, and I am now talking about matter, form, process and meaning.

The perspective of matter is the perspective of physics and chemistry, where you deal with material structures, with energy, with entropy, with all these concepts of physics and chemistry.

The perspective of form is really the perspective of complexity theory where you deal with concepts like organization, complexity, pattern and so on.

The process part is very broad because there can be physical processes, chemical processes or cognitive processes. This is where cognition comes in, in the process part.

And then, "meaning" is a sort of catchword, or a label, for the whole dimension of consciousness and culture, where we have values, purpose, goals, strategies, conflicts, power, and so on. Power is actually a very interesting part. One of the drawbacks of many previous attempts to use systems theory, or complexity theory, to talk about social issues has been that those people were unable to deal with the issue of power. For example, when they talk about business organizations, about how to make the organization more relevant, how to make it work more smoothly, people would often say, “when I go back from the seminar on Monday morning, my boss says we have to increase market share, we have to fight off the competition,” and so on. The systems theorists could not really fit that in, because from the very beginning power was nowhere in their framework, nor were values or meaning. This is what is different in my approach. I include the dimension of meaning from the beginning.

Meaning and power

FP — How do you establish the connection between meaning and power? How does that connect actually?

FC — As I said, meaning is a label for a whole range of phenomena. Over the time that I wrote my manuscript, that perspective had different labels. I started calling it "purpose," then I called it "consciousness and culture," and finally I settled on "meaning." It's a very important term in cognitive science. People talk about the hermeneutic dimension of cognitive science. Social Scientists like Habermas or Giddens talk a lot about meaning.

Now, the key to this whole domain that I labeled with "meaning" is the ability of human consciousness to form mental images. That to me is the key. If I am able to form a mental image of something that either does not exist, or doesn't exist yet, or is not here at the moment, I can say: this is what I want, and I am going to work toward it. So, the whole idea of purpose is based crucially on our ability to form mental images: strategies, plan, all that.

Moreover, I can hold in my mind two or more alternative mental images, and I can say: “There are two different possibilities, and I prefer one over the other.” This is where values come in. They are based on the ability to make a choice between different mental images. And as soon as you have values, you'll have conflict. Indeed, you cannot deal with social systems in a significant way if you don't deal with conflicts. Power, then, is the way to resolve conflicts. It's not necessarily power in terms of domination or force. It can also be power in terms of incentives or persuasion or charisma. All these are forms of power. Power is a way of resolving conflicts. In any community, there will necessarily be conflicts, and the community as a whole will encounter situations in which it will have to decide to do either one thing or another. Since time immemorial, communities have given power to certain individuals, based on certain qualifications, to make these decisions for the community. In more complex communities and societies, this power becomes institutionalized, so that you have institutional structures that are very often hierarchies of power. For instance, in a company the organizational hierarchy is a hierarchy of power with certain rules of behavior — who reports to whom, who is responsible for what decision, and so on. This structure is formed not so much because people like power (although this is also true), but because it is an effective way of dividing tasks and labor, so that the company as a whole can act in an effective way.

So, power derives from conflicts, which come from values, which are based on our ability to hold mental images.

Metabolism

FP — Let's go back to the life sciences. The first question in your first paragraph is "What are the defining characteristics of living systems?" What is the short answer to that?

FC — Well, the one-word answer is metabolism. Let me take you through a little exercise.

If you go around the life science departments and ask, “What is the essential characteristic of life?”,-- most people will point out to you that the things that are alive are made of cells, and inside the

cells we find macromolecules, long strings of atoms — the proteins, enzymes, lipids, the DNA and so on. To make it even simpler, you can focus on DNA, and you can say, "All you have to do is look for DNA. If there is DNA, it's alive; if there is no DNA, it's not alive." The problem with this definition of life is that, when an organism dies the DNA does not disappear. The DNA is a molecule, which itself is not alive. So, in this wooden chair, for instance, most of the DNA of the wood is still there. My favorite example is that of a team of German scientist who studied the DNA of a Neanderthal skull. These were bones that had been dead for a hundred thousand years or more, and yet the scientists were able to map the sequence of genes in its DNA. So, DNA is not the answer. At the very least, you would have to say we need something that contains DNA *and* which is not dead. But that, of course is a tautology, to define a living organism as something that is not dead.

So, the answer lies not in the structure of the cell, the answer lies in what philosophers and poets have always called the breath of life. When something has the breath of life, it is alive. In scientific terms, that's what we call metabolism.

Metabolism is the ceaseless flow of energy through a network of biochemical processes, which allows the organism to maintain itself, to repair itself and to perpetuate itself. This metabolism is the essential characteristic of life. Then, if you ask what metabolism is in detail, you have to go into the details of biochemistry and cellular biology.

The cellular network

FP — I am not a biologist, and neither are most of my readers… How do you explain that we should understand the cell as a network?

FC — Let me contrast a living cell and a machine, say a clock or a car. When you build the machine, you manufacture the parts; you do some machining and engineering to manufacture them as precisely as you can. Then you fit them together according to a preexisting design. And then the machine works and you can mass produce it.

A living cell works quite differently. It's a network of processes that actually continuously build the parts. The parts from the cell do not come from a factory outside the cell; they are created by the cell itself. And when I say parts, I mean all the macromolecules and cellular structures.

Small molecules come in through the cell membrane — the food, the oxygen, the carbon and so on. The food comes in and is broken down. But each macromolecule, for example each enzyme, which is a protein with a very complex structure, is synthesized by the cell itself. The process of protein synthesis is now quite well known. It's a complex process which involves the genetic information in the DNA, in the genome. The DNA strands unwind a little bit, and then the part that is needed for the protein is copied onto a macromolecule called RNA. Then the RNA takes that information to a place where the protein is built. It's called a ribosome and at the ribosome, the protein is synthesized from elements called amino acids. They are put together in a certain order, and that order is given by the genetic code.

This is the basic way of constructing a protein. That process needs the basic elements, the amino acids, which float around in the chemical soup around the ribosome. It also needs energy to capture the amino acids and put them into place. In biochemistry, these processes can only happen if there are catalysts. They are facilitators of the process and are not affected by the process. They are part of the reaction but come out of the reaction unchanged, and can go on to catalyze another reaction.

The energy comes in the form of special molecules called ATP. They are special kinds of phosphates that change their structure in various steps, and in each step they release energy. They are energy carriers.

The catalysts are the enzymes. A dozen different enzymes are needed for that protein to be built. Where do they come from? Everything has to come from the cell. The ATP molecules are built in the mitochondria. They are the power houses of the cell. They form the energy carriers to supply the entire cell with energy. The enzymes are built in the same way as proteins are built, because they themselves are proteins. Each of the enzymes that helps in the synthesis of a protein has itself been synthesized somewhere else in the same type of process. If you put all that together you have a network, and a very complex network, because each molecular structure, each molecular unit, has been produced by other molecular processes, has been catalyzed by other molecular units. In this way, the entire network continually produces itself. You can draw a diagram of the various cellular structures, and you will see that when the energy carriers are created in the cell's powerhouses, they swarm out over the entire cell and go to all the processes where energy is needed. The same thing happens when enzyme are created. They too swarm out, and the amazing thing is that these processes happen very fast. Synthesis of very complex molecules goes on all the time and goes on very fast. The macromolecules constantly travel to different areas where they are engaged in chemical processes. So these material structures that form the links between two processes are the links in the network. The network is a nonmaterial network; it's a functional network where these structures interconnect biochemical processes.

FP — When you use the word "network," sometimes you give the impression that it is a pattern, some times you give the impression that it is a process. There are structures in there. That is a useful word that you do not have to explain each time. It begins to be a paradigm in the sense in which Kuhn uses the term.

FC — Very true. Let me be precise about the cellular network. There are three elements in there. There are processes, which are processes of production. There are structures, the things that are produced. And these molecular structures, once they are produced, go on to contribute to other production processes. They are the links in a network of production processes, which is a specific pattern. So, you have processes, structures, and patterns.

And you are right, I don't need to define network. When you go into more details and deal with different kinds of networks you need to define these specific networks. But everybody knows what a network is.

FP — Kuhn says that you use it because you don't define it. That's why it is useful and becomes a paradigm. Let's move to another issue, autopoiesis. What is it?

FC — It is exactly what I just explained to you. That is autopoiesis. Over the years, I came to use less and less technical terms. I use "autopoiesis" in my book, but I give many lectures where I don't use it at all. What "autopoiesis" means is self-generation. Living networks are self-generating. The unifying pattern of life is a self-generating network, an autopoietic network.

Networks and complexity

FP — What is the difference between something that is complex and something that is organized in a networked fashion? At times you have the notion of complexity and at times the notion of links. They appear to be almost two versions of what networks are.

FC — There are two issues here: metabolism is the totality of life processes, and it involves a continuous flow of energy and matter through an organism. The food comes in and flows through a network. It is being processed, digested, taken apart, recombined. And this always creates waste.

So, there are these two aspects: the flow process and the network pattern. Both are part of metabolism.

With regard to complexity, I think the main characteristic of a complex system is that it is nonlinear. Complexity theory is a set of mathematical concepts and techniques that deal with nonlinear systems. A network, by definition, is nonlinear. The significance of this property was recognized already in the days of cybernetics. The cyberneticists were very interested in networks but did not have the mathematical tools to deal with nonlinearity. They invented all kinds of mathematical techniques, but they did not have the powerful computers that we now have to deal with nonlinear equations and to simulate nonlinear systems.

A network is intrinsically nonlinear. Moreover, the equations that describe the flow process in the metabolism are also nonlinear. So you have nonlinearity in the mathematical expressions of the flow process and in the network structure. Prigogine linked nonlinearity to states far from equilibrium, from thermodynamic and chemical equilibrium. The higher the non-linearity in the equations, the farther away the system will be from equilibrium. The major achievement of complexity theory, which is technically called nonlinear dynamics, has been to show that a system far from equilibrium has very unusual and unsuspected properties, in particular the process of emergence, or bifurcation, where new structures or new behavior emerge from points of instability, or bifurcation points.

This is the essence of complexity. Some people even define complexity by saying the more bifurcation points in a system the higher the complexity.

There are many people now who study networks and who do not apply complexity theory. This is still something to come. And once they will do it, there will be huge progress; there will be a quantum leap, if you wish.

FP — Using your terminology, we could say that most scientists are limiting themselves to the pattern and maybe the structural perspective. But they do not put in enough of the process, because when you focus on the process, then you have the emergence.

FC — That's true. You could say that. I had not thought about it in this way.

Network approach and systems approach

FP — What's the difference between a network approach and a system approach? You use both terms. One may be older than the other…

FC — The systems approach is older, and it means an approach that focuses on relationships rather than separate objects. And it focuses on processes rather than structures. Exactly what you just said. The network approach grew out of the systems approach when people focused specifically on the network pattern.

Actually, come to think of it, it's not really true that the network approach came later. Ecologists introduced the term ecosystem, which was a major advance in making the systems terminology acceptable and publicizing it. And they also introduced the food web and the network approach. From ecology, network modeling and network thinking went into biology and into various other fields. This happened in the 1920s and '30s. So, you could say that systems theory and network thinking really arose together.

In the '30s and '40s, there was the school of Ludwig von Bertalanffy, which was called general systems theory. He was a biologist and worked on theoretical biology, and he focused on open systems. He was a predecessor of Prigogine, but he did not have the mathematical tools to describe nonlinear systems. The cyberneticists did not focus on the physiochemical processes but on the patterns, and they very much dealt with networks.

FP — It would be interesting to do a history of network thinking…

FC — Yes, that would be interesting. This is the kind of study that would be great for a graduate student.

FP — What allowed you to move from one level to another, from one science to another, from biology to cognition to social networks? Why can something that works at one level be applied at another? What gives you the right to use the same metaphors at those three levels?

FC — My firm belief is that life is a unified whole, that we don't have biological life, and social life, and mental life or psychological life, and spiritual life. I think this is all part of the whole process of life, which has evolved on this planet for the last 3.5 billion years. It has evolved, as I said before, by using the same patterns over and over again. I make somewhat of a leap of faith here by saying that, since life has used the same patterns over and over again, I believe that, when I talk about networks of communication and compare them to biological networks, I can find similarities in the patterns. I have done this to quite some extent, and I have tried to push the parallels as far as I can. In particular, I have

put together a whole list of similarities between networks of communications and networks of biological processes.

FP — You are talking about "belief," a "leap of faith"…

FC — Yes. The justification is a belief. But what I actually say about similarities comes from observations. And I think this is typical of science. When you start with a theory or a hypothesis, it's always a leap of faith.

A "science of networks"?

FP — There are some scientists, for example Laszlo Barabasi, who talk about the emergence of a "science of networks." Do you believe in that, and what does it bring to you? What do you learn from that? How does it help you?

FC — This is a big subject. There are very few people today who have used complexity theory to study networks. As an example, let me use molecular evolution, which I mentioned a while ago. There is now a school of thought that does not believe that life evolved from a uniform chemical soup, which was the original Darwinian idea, but that bubbles were formed before, which had soapy or a fat membranes. They were made of lipids, which are fatty and oily substances. If you mix soap and water and shake them you'll have bubbles. If you mix oil and vinegar (which is a watery substance) you'll get bubbles quite naturally. There are very simple physical laws that say, when you have lipids in water and you shake or disturb this mixture, bubbles will form spontaneously. And the idea is that these bubbles formed in the primeval oceans when they cooled down, and that life evolved inside the bubbles. So first you had the membranes, or protomembranes, and then you had the evolution of complexity inside these membranes.

Now, the big difference is that, once these bubbles are formed, they create two kinds of spaces, an outside and an inside. And the laws of physics and chemistry are very different inside and outside. We are talking here about micro-bubbles, which give rise to a very different type of micro-chemistry. It has to be a network chemistry because things bounce off from the walls of the bubbles all the time. The space is small, so the molecules are forced to interact with one another in a much more intense way. And this produces radically different results.

For example, substances that are not synthesized with great probability on the outside, are synthesized in abundance on the inside. To come back to your question, we don't know how to deal with this network chemistry, we have not yet developed the appropriate concepts and methods. We have just started; it's just the beginning.

That's why I think that the analysis of networks and the application of complexity theory to the theory of networks will be a tremendous advance.

Another example would be morphogenesis, the origin of biological form. There, you have a genetic network interacting with a cellular network, which is subject to certain physical and chemical

constraints from the environment. Out of this complex interaction grows, say, the leaf of a plant or the shape of a bone. Little work has been done in this area.

FP — Could the science of networks be used for these next steps?

FC — Yes absolutely.

FP — Is "network" a paradigm or a metaphor?

FC — Definitely a metaphor. My understanding of the Kuhnian notion of paradigm is that it is a set of concepts, values, and techniques that define useful problems, that define the research agenda. "Network" seems to be a little too narrow for a paradigm, not rich enough. It's a pattern and a powerful concept. I am more comfortable with calling it a metaphor than a paradigm, because a paradigm also includes values, norms of behavior and all that.

FP — If you use it in the social sciences you may want to come back to the paradigm notion because you have values, and meaning, then it could become a paradigm. Within your own thinking, you could raise this question.

FC — Perhaps, but we are talking about values in a different way. The values are the values that are shared by the scientific community. They tell us what we should and should not do. For instance, cloning. If you say "We should not clone human beings," that's more of a paradigm. It expresses a respect for life… This is not the value that's embedded in the object you study but the value shared by the scientific community doing the studying.

Ecodesign

FP — At some point you said: "The design principles of our future social institutions must be consistent with the principles of organization that nature has evolved to sustain the web of life." Why should it be so?

FC — The answer is the notion of sustainability. Over the evolution of life, nature has developed certain patterns of organization that allowed life to survive for billions and billions of years, using the very same molecules of air, water, and soil. And not only to survive, but to unfold and increase its diversity, and so on. These patterns of organization are patterns we need to understand and to apply to our human design. This is what is called ecodesign today.

Now you could also say: "we are going to improve on nature," and we are not using the natural patterns of design, we are using something better. But the chances, I think, are very slim that we will find something better. Of course, our recent history of the last few hundred years has shown that we are dramatically wrong in using the patterns that we are using now. For instance our economics are based on fossil fuel which is not sustainable. And in the long run we are killing ourselves.

The global economy

FP — At another moment, you write that you want to change the values of the global economic network. How do you do that?

FC — This is one area where I can illustrate the power of my theoretical framework. Because I have included meaning, values, culture, consciousness, etc., right from the start, I can use my theoretical framework to analyze the global economy, and values are a crucial part of that analysis. Others cannot do that that. When ask them, "what about values?" -- they would say: "that's not my domain; I'm a scientist," or something like that. So, what I am saying, following Manuel Castells, is that the global economy is organized around networks of financial flows.

There is a global network of computers that allow investors and speculators to invest their money anywhere in the world into any project, any economy, in any country and to withdraw it immediately if they feel like investing it somewhere else. These are processes that happen within minutes, within seconds. So there is a global, electronic casino going on, with billions of dollars sloshing around the planet every day.

In order for this to happen smoothly, in order not to impede these global financial flows, certain rules have to be maintained. These are the so-called "free-trade rules" imposed by the World Trade Organization. And here is one value that is underlying these various complex rules of the neo-liberal economic theory. The one value is that making money is always better than anything else. So, when there is a conflict between making more money or protecting human rights, taking into account health considerations, protecting the environment, protecting democracy, or whatever other values we have, making money is always more important for the WTO and therefore it has to take preference. This value is programmed into today's global economy. It's a single value, a quintessentially capitalist value.

What I propose, together with many colleagues, is to change the value system and to incorporate a certain minimal ethic into this global network. To say, for example, that workers, all over the world need to be paid living wages. That does not mean that they will be paid the same. You can argue that the living wage in Indonesia is less than in Chile or other parts of the world. But the principle is an ethical principle, that living wages should be paid. Another would be that toxic substances should be handled with certain care. That certain health considerations should be taken into account, and so on.

There are already values that are sort of on the margin: that you will not trade in endangered species, for example. There are NGOs who have developed a whole set of new rules that would expand these values.

FP — I think I understand the rules you have in mind. The problem is "how do you change the rules?"

FC — I think that can be addressed only politically. Technically, it is absolutely possible to reprogram the global economy according to different values.

The environment and the social sciences

FP — I quote from your book: "The design principles of our future social institutions must be consistent with the principles of organization that nature has evolved to sustain the web of life." Why should it be so?

FC — I think that what is new in our era, in the 21st century, is that in everything we do we need to take the natural environment into account. We depend on it and we influence it; we have a very strong impact on it. That was not so important in previous centuries where the world population was small and natural resources were abundant. Although you could say it was not morally defensible, people could wreck the environment in one place and just move on to another place to find a pristine environment again. They would find clean air, clean water and natural resources. With our world population today that's no longer possible. Everything now is interconnected, both socially and ecologically.

So we always need to take the natural environment into account, and this is one of the big problems with the social sciences. They are traditionally interested only in social phenomena. They tend to treat social phenomena as if they happened in a vacuum, and do not see how we are embedded in ecosystems. I feel very strongly from my background in the natural sciences that the principles of ecology must be seen as laws of sustainability that are as stringent as any other natural laws. If we continue to use fossil fuels, that will be to our detriment and eventual disappearance from the Earth. That is as stringent as to say, when you stand on a cliff, you cannot walkout into thin air because there is something called the law of gravity, and it will pull you down. We know that one does not walk into thin air off a cliff.

Similarly, we have to recognize that we cannot have processes of industrial production where we take natural resources, manufacture goods, create a lot of waste in the process, and then throw away the goods themselves. This is not how nature works. The understanding of ecology tells you that species who act like this do not survive. Species who disregard the basic principles of ecology will not survive in this interconnected world.

This is why we need to live sustainably. Living sustainably means taking these laws and principles into account and reflecting them not only in the design of our material goods but also in the design of our social institutions.

FP — You are stating the principles of life. How does that impact politics and social sciences: anthropology, sociology etc.? And how does the network metaphor or paradigm apply to the social sciences?

FC — The first part of your question seems to imply that I use the social sciences to make a political argument. I don't see that as a political argument. It's an argument of common sense. If we recognize certain laws of nature and recognize that disregarding these laws we will harm ourselves, then we had better take it into account. That's not political, that's just common sense.

FP — Common sense may be a political argument, as we know too well.

FC — Sure. Maybe what you want to get at is, that I use an understanding of the natural world to construct a normative framework. To say "this is what we should do."

FP — Exactly.

FC — Yes, That is true.

FP — Let's go back to the other part of my previous question: how do you see the impact of the network metaphor on the social sciences? It's not a normative issue. It's a matter of understanding and of knowledge. What can it bring to the social sciences?

FC — The two parts here are related. The first part says that nobody today can disregard the natural environment without causing harm to humanity. We can apply this to the social sciences. Social scientists cannot put themselves and their discipline above nature or separate it from nature, from the material world. They need to get interested in the material world, try to understand the material world, because it is a context of all our actions that needs to be taken into account.

To be interested in the material world does not mean that social scientists need to become biochemists or physicists. That's not necessary. But they need to understand the laws of sustainability, which are the basic principles of ecology. They need to understand the basics of how ecosystems work. That does not require technical knowledge. It can be understood in very general ways.

I can tell you that it is very interesting to look at an ecosystem and ask, "how does it organize itself for long term survival?" Its patterns of organization were developed in evolution through trial and error and through natural selection. There is no design in an ecosystem. So, how do ecosystems organize themselves to maximize their sustainability? You can identify certain principles. One key principle is the network as the fundamental organizing principle of ecology. When you look into this in greater depth, you find that the network is not only an organizing principle of ecosystems, but of living systems in general. In the 1920s, when ecologists began to speak about food webs, other scientists used this network concept and transferred it to biology, looking at an organism as a network of cells, and at a cell as a network of molecules and so on. They discovered that the network is the basic pattern of organization of all life.

Human organizations

FC — So, now we can ask the question, "Is a social system a living system that can be analyzed in those terms?" I have struggled with this question for many years. What I have done is to look at human organizations, because that is a smaller scale than to look at society as a whole. I asked myself the question "Can a company be regarded as a living system?" First, I tried to understand whether we can use the living system as a metaphor for a company. Can we talk about "the living company" as a metaphor? There is a very good book by Gareth Morgan, a Canadian organizational theorist, called "Images of Organization." He talks about the machine image, and about the company as a brain, as a prison, as all kinds of things, including a living system.

Then I wanted to go beyond metaphor and imagery, and really see if you can understand a human organization as a living social system. I tried to follow the network approach, and in particular the

work of the German social scientist Niklas Luhmann, who took the concept of autopoiesis from Maturana and applied it to social systems. Luhmann concluded that a social system is a network of communications. It is self-generating (or autopoietic), so that each communication generates ideas, information, thoughts, and meaning, and thereby triggers further communications. So, the whole network generates itself. I have used this view of social systems to analyze human communities. By the way, I think "community" is a good term to use, because people have a direct experience of community. So, I looked at a community as a network of communications, and made a detailed comparison between biological networks and social networks.

One difficulty that has plagued all the discussions of how to deal with social systems as living systems, has been to identify the space in which the social processes take place. In a cell, you have a physical space and you have chemistry going on in that space; so you can write equations and talk about gradients, concentrations, densities, and things like that. It's pretty straightforward. With social systems the question is: do the individuals within the social system — the nodes in the network — operate in a physical space, or in a mental space, or is there something like a social space?

These are very difficult questions, and I don't think they have been resolved. But Luhmann at least started by saying social systems are networks of communications. I tried to expand that idea by comparing social networks with biological networks. In a living biological network, there are production processes, and the network produces material structure. You can say the same thing in a social network. In a business organization, for example, it's quite obvious that the main purpose of the organization is to produce goods and to sell them. So, there are products. The organization is a network of production, but there is also a nonmaterial dimension where the products are nonmaterial structures — ideas, thoughts and so on. In the book, I call them semantic structures. So, there are material structures and semantic structures, and social networks produce both, whereas biological networks produce only material structures.

You can go on and look at the material structures produced by social systems, and you will see that they are quite different from material structures produced by biological networks because they are usually reproduced for a purpose, according to some design, and they embody meaning. The painting here behind you is produced for a purpose; you could say the artist wants to sell paintings and make a career; but there is more to it — the purpose of self-expression and other goals an artist can have. And the painting embodies meaning, including cultural meaning. This is true also for this coffee cup. It embodies cultural meaning. The whole field of anthropology is concerned with that.

I have made two parallel lists with the characteristics of biological and social networks. Biological networks operate in the realm of matter; social networks operate in the realm of meaning. Both produce material structures, but those produced by social networks are always connected with the realm of meaning. I also looked at boundaries, which is very interesting because part of the definition of a self-generating, living network is that it generates its own boundary. It needs a boundary to acquire an identity; otherwise it could not exist as a unity in the world. In a cell, the boundary is not a boundary of separation because it's a semi-permeable membrane. It is a boundary of identity; it restricts the chemical processes that can take place inside the network, because it lets in only certain things and not others.

In the social realm, when you look at a community, there is also a boundary, but it's not a topological boundary. It does not go around a community in a topological sense. It surrounds it in a metaphoric sense. The boundary of a community is a boundary of belonging, a boundary of loyalty, a boundary of expectations — there are many words you can use. It's always a boundary of meaning. The continuing interactions and communications within the boundary create a culture, that is, a shared system of knowledge, beliefs, values and norms of behavior. That's the standard definition of culture.

This is a very interesting situation. You see, the boundary is created by the system, and at the same time it feeds back on the system and restricts the behavior of its individuals. That is true both in biology and in the social sciences. Taking all this together, I have very good evidence for the fact that it's useful to apply the network concept to social systems. This work is far from complete. There are many problems when you try to be more specific. But it looks very promising.

FP — What do you see at the very edge of this research?

FC — Well, let's talk again about, morphogenesis, the generation of biological form. I said before that we need to understand both the biochemistry and the nonlinear dynamics of the biological network. Then we need to see how this nonlinear dynamics, this network of chemical processes, encounters the physical and chemical constraints of its environment, and how this results in a limited number of forms. Mathematically speaking, it results in a limited number of attractors. This is how you can explain the generation of biological form. The genetic part determines certain parameters. A certain plant will respond to chemical conditions in a certain way, another plant will respond differently because it has a different genome.

This is much more precise than just saying "we have a network, and we have a boundary, and we have production of material structures." I can translate that general description into the social domain. But what about the more specific descriptions? What about the genesis of biological form? Can we compare this with the genesis of semantic structures, like language, meaning culture and political systems? I think it would be extremely interesting to do this.

FP — What is the space in which this takes place? What are the important nodes?

FC — There is something very important here. In extending the framework of the network approach from biology to the social sciences, I assume a commonality of patterns; I assume that life always generates the same kinds of patterns. There is a network pattern in biology, and there is a network pattern in the social sciences, and so on. But in order to understand the details of the network, you have to say, "What are the nodes, and what are the processes that are involved?" In a biological network, the processes are biochemical processes. In a human community, they are processes of communications, which involve values, ideas and knowledge; and, very significantly, they involve conflicts, relationships of power and all that. So, we can use complexity theory to learn about the network pattern and apply this to social science, but we need political theory, anthropology, philosophy, all kinds of social sciences, to explain what's going on in the processes, just as we need our biochemists to explain what enzymes do in the cell.

FP — That's where your work with Manuel Castells can be significant in the application of a network perspective in the social sciences…

FC — Absolutely. One thing I have learned from him is that in society, there is always conflict, and there are relationships of power. But in a network society there are no absolute centers of power. This does not mean that everything is equal. A network can be very asymmetrical and certain nodes have a lot of power while others have very little. But networks need to take all the nodes that are in the network into account. There is a mutual dependency among all of them. Although some of them will be more powerful than others, they cannot ignore the less powerful ones because there are so many nonlinear connections that things will inevitably come back to haunt you if you ignore other things.

Another thing I have learned from several theorists who study networks is that the importance of a node in a network comes from its connectivity. Nodes that are more connected are more important. They are not necessarily leaders in a qualitative sense, but they are more connected. And I think I am just realizing now, that there is an interesting connection to cognitive science here, because this is how one can define intelligence, in terms of cognitive connectedness. So, intelligent nodes are more important, because they are more connected.

FP — We are now in the area of information. You have not used this word, in this sense at least. You have mentioned matter, patterns, etc. How do you see the difference between information and meaning in your approach?

FC — I have thought a lot about both. I use "meaning" as a label to include the social dimension in this framework. I define meaning as the experience of context. I have known for a long time that it has something to do with context. Gregory Bateson wrote about meaning and context, but he did not connect the two in a precise way. I believe now the connection is that meaning is an experience. When we find something meaningful we have an experience of a context.

Let me give you a few examples. Let's begin with the meaning of a word in a linguistic context. In order to explain what a word means, for example in a dictionary, we have to give the context. The meaning of the word always resides in the context, and it's a never-ending game. In my seminars I sometimes use the example of a group of lawyers sitting around a table and having a discussion about the meaning of a legal text. They very precisely analyze the sentence structures of the text, compare it with other legal texts and with other cases, and will derive a precise meaning of that legal text by studying its context. This can be a purely intellectual exercise where they apply their knowledge of the law. Now, suppose that one of them remembers that a very similar case was one of the first cases he ever argued in court, which launched his whole career. For that lawyer, the text is meaningful at a very personal level. It acquires an emotional charge, which is quite different from the linguistic and legal context. Typically when we say "The meaning of something is that and that," we refer to the intellectual context. And when we say "Something is meaningful," there is emotion in it. When the context of something includes my own self, then it becomes meaningful in a personal way.

FP — Context, then, can be seen as a set of relationships…

FC — Yes, absolutely. It is a set of relationships with other things, That's why it fits with the network.

FP — There is an interesting notion, which is that of the "text of the network". Would you think that in the same way as it is legitimate to go from biology to cognitive sciences to social sciences, that there would be a need for a "network text?"

FC — I have not thought about that. It's a very interesting question. Do you mean that, rather than writing things down linearly, we could write them hypertext fashion? But let me come back to your previous question about information. I have not, in my written work, connected meaning and information, although I have written about both. I think the connection is that meaning is the context and when the context is stable, and we know it well, then we can abstract part of that context, parts of this network of relationships, and create a short "piece," and this is what we call "information."

I'll give you an example. I can ask you, what's the time? And you say 2:30. That's a piece of information which is quite clear cut. Many people think, it's an objective piece of information. I can pick it out from the world around me and communicate it to you. That's true, but it requires a lot of contextual ideas. It requires a common view of the solar system, of how we measure time with the revolutions of the Earth. It requires a cultural consensus to divide the day into 24 segments and each segment into 60 minutes, and so on. That's just convention. You could do it in many other ways. In California, if I say to a kid it's 14:30 he probably won't understand what I mean, whereas you, being European, know exactly what I mean. It's a matter of cultural context. That whole context is stable; we share it, and therefore I can abstract it and call it "a piece of information."

I learned this from Francisco Varela a long time ago. He convinced me that there is no such thing as information in nature . Information is a human construct. We discussed this with the example of genetic information. Everybody says that DNA contains genetic information. But that's again abstracted from a whole context of a metabolic network, which we need to know in order to understand the information that is in the genes. So, meaning is related to context, and information is also related to context, but in different ways. Information is an abstracted piece of context and meaning is the experience of a wider context.

FP — You had something to say about hypertext…

FC — Yes, that's more anecdotal. Anybody who works with networks, nonlinearity and patterns has the problem that, whenever you speak or write, you have to do it in a linear way. This raises the question of how can you write linearly about a nonlinear reality, a nonlinear system. There are several ways of dealing with that. One way that I use extensively is to use nonlinear conceptual diagrams. I put words on paper in a pattern and connect them with lines. I have adopted a system over the years where I use different kinds of lines to picture different kinds of connections.

FP — Do you use software?

FC — No, I find it too slow. I prefer working with pencil and paper, and I use this technique extensively. This is one example of how to deal with nonlinearity. Another one is how I write my books. Over the years I have developed an elaborate system, even a ritual, of writing. I prepare my books for a very long time. Obviously, I do a lot of research. When that is done, I have a stack of notes that are pretty structured. And then I go about structuring the actual book. When I decide, I have enough information and I can start writing, I spend several months to structure the book. I map out the chapters, and the sections in each chapter. Then, when I write, I start from the beginning and write the chapters in sequence. But when I start with chapter one, I know exactly what will be in chapter 5, because I've mapped it all out. This allows me to make many cross references, even to things I have not yet written. In my books, there are always abundant cross references, backwards and forwards. They complete the conceptual network. The text is linear, but the cross references provide the nonlinear connections.

Recently, I saw a paper by a colleague of mine, Amory Lovins, on the Internet, in which the references are all hyperlinks; they are not numbered. In the reference section, the author gives the corresponding page number of the hyperlink, but the links themselves are not numbered. It's an interesting new technique, and you could do the same with hyperlinks between different parts of the text.

FP — Have you read "One Thousand Plateaus" by Deleuze and Guattari?

FC — No

FP — I think it's a very important book for what we are talking about. They use the concept of rhizome. The construction of the book is in plateaus which they take from Bateson. What strikes me in the way you build your books, is that you build them in a very solid way and you can have connections, but it's fixed while the structure of the mind is not fixed because you can go from one place to another.

FC — Another thing I did many years ago when I was teaching a course, was to draw a conceptual map in preparation for every lecture. During the lecture, I would transfer the map onto the blackboard. This technique has a great advantage, because usually when you teach with a blackboard, especially in science, you write a lot of equations, you take up a lot of space. And then you don't quite know what you can erase and what you need to save on the blackboard. In my system, there is nothing to erase, because I already know the final network. I just put in the words, and I put them in the right places from the beginning. Then I connect them. I also told my students that they should not copy the whole thing. They should rather listen to me, and I would give them handouts at the end, so they could take the finished conceptual diagram home. It's a lot of work. But the advantage is not only that you don't need to erase anything; you can also start from any point, because it's a network. And you never get lost.

FP — You mentioned that you were interested in communities, and you mentioned the fact that in businesses organizations there are communities, or informal networks. People might not pay enough attention to this in institutions and outside.

FC — This was an important insight for me when I began to analyze human organizations as living systems. I heard many people talking about "the living company," or "the living organization," as a metaphor. They would give talks on the emotionality of a company, on its deep purpose and so on. All this

sounded a little phony to me because I knew that what is really going on in a company has to do with competitive advantage, shareholder value, power struggles and so on. And they never addressed any of these issues. They would brush them to the side.

On the other hand, I also realized that people who only speak about the structure of organizations and cannot talk about processes of emergence, creativity, and things like these. Finally, after many years, I came to the conclusion that any human organization has a dual nature: it is a social institution, you could even say a social tool, designed to achieve a certain purpose, such as producing goods, making money, disseminating knowledge and so on. On the other hand, it is always a collection of communities which are now called "communities of practice" by organizational theorists. These are the informal networks in the organizations. And this is the part of the organization which is alive, and which I can analyze in terms of my network concepts. This living part, the informal networks, is where the flexibility lies, the learning capability, the creativity.

Now, it's important to realize that a human organization always needs both. It needs a formal structure which embodies the purpose. These formal structures are always structures of power. They are the structures where power is managed and communicated. When you have a hierarchy in an organization, it's always a hierarchy of power.

FP — What about the informal part that you have mentioned?

FC — Organizational theory and management theory generally deal only with the formal structures and not with the informal ones. The formal structures are needed for the routine work; they are needed for the company to function smoothly, for the distribution of tasks, and all that. But the informal structures are where the creativity, flexibility, and adaptability lie. An organization always needs both.

Social network theory

FP — I would like you to explain now what you think of the state of the social networks theory and how it fits within this greater framework

FC — I must tell that my knowledge there is very limited. I am still looking for theories and theoretical frameworks that I can use to elaborate these ideas on networks, and I have not found much. Castells is one of the big exceptions. Then there is a sociologist in England, at Lancaster University, John Urry, who has written a book called "Global Complexity." He analyzes networks, and he also has a critique of Castells that is very interesting. There are also some French sociologists who have developed a theory they call "actor-network theory," which I find very confusing and full of misperceptions. So, all in all, I have not found much in terms of effective network theories.

FP — It seems easier to find a methodology of how to map a network than any serious theory to understand what's at stake. Luhmann seems to be much closer to giving a theoretical approach. One last thing: how do you connect all this with your social agenda today?

FC — This is very simple, although it emerged for me through many years. The core of my social agenda is sustainability. I work as an environmental activist and educator, and my key aim is to help build a sustainable society. When you do that, you first have to really understand the concept of sustainability. I define an ecologically sustainable society as a society that is designed in such a way that its ways of life, businesses, economy, physical structures, technologies and social institutions do not interfere with nature's inherent ability to sustain life. The outstanding characteristic of the biosphere is that it has sustained life for over three billion years. And we are now seriously interfering with these processes that nature has evolved to sustain life.

What we need to do is first to become ecologically literate, to understand the principles of organization that ecosystems have evolved to sustain life, and then we have to redesign our technologies and social institutions accordingly. When you try to understand how ecosystems organize themselves, this leads you very soon to understanding how all living systems organize themselves. So, the exploration of sustainability becomes inextricably linked to the question of the nature of life, the nature of living systems.