Chapter 17

Bridges, Connections and Interfaces – Reflections over the Meso Theme

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1. The grand bridge: From the very small to the very large

In the huge bridge between the very small – the micro world – and the very vast world of macrocosmos an infinite number of layers ”in between” can be envisaged. However, modern physics has pointed at the connecting features between the very huge and the extremely small. The studies e.g. at the Kamiokande and Super-kamiokande laboratories in Japan – or rather ”observatories” – have shown neutrinos from the sun but also e.g. neutrinos considered to have been emitted by the explosion of the supernova SN1987A (Broggini *et al.*, 2003).

Supernova neutrinos are e.g. considered to be essential for improving our knowledge about the emission models in gravitational collapses. The authors in their overview article from 2003 formulate this in the following way: “The detection of high energy cosmic neutrinos represents one of the most exciting future prospects in astrophysics… Such studies are expected to play an important role in unravelling the mysteries associated with major cosmic accelerators, such as active galactic nuclei and gamma-ray bursters.” Neutrinos in cosmology has indeed had a strong impact on our view of particle interactions and paved the way for the recent impressive experimental achievements in cosmology. Thus the understanding of the very small and fast – e.g. neutrinos – has been shown to be intrinsically linked to the understanding of ”the extremely large” cosmological scale in space and time.

Thus, when we have approached the meso-scale issues in this book we have constantly to remind ourselves that there is this grand coupling between the level of the very small and that of the very large – at least in terms of a physics outlook.

However, it is interesting to note that the perspective on phenomena to quite high a degree depends on your “own” scale of frame. The case is made by Nigbel Goldenfeld & Leo P. Kadanoff (1999) where they note the not so surprising fact that fluids frequently produce complex behaviour. These can either be highly organised as in a tornado, or chaotic in a highly turbulent flow. But what is *de facto* seen rather often depends on the size regime of the observer. “A fly caught in a tornado would be surprised to learn that it is participating in a highly structured flow”. Thus the issue of what is ”meso” in a specific context depends on how the phenomena involved relate to each other, and not the least the way how the observer system relate to what is observed. Thus as the authors stress: “To extract physical knowledge from a complex system, one must focus on the right level of description.” In the ”fluid dynamics example, the large-scale structure is independent of a detailed description of the motion on the small scales. We can exploit this kind of ‘universality’ by designing the most convenient ‘minimal model’. For example, most fluid flow programs should not be modelled by molecular dynamics simulations. These simulations are so slow that they may not be able to reach a regime that will enable us to safely extrapolate to large systems”.

2. Life as phenomena at the meso level: The issue of reductionist couplings between levels

What is interesting is that life seems to appear at the ”levels” in between the very large and the very small. However, the simple observation that bodies of humans and other animals occur in a mid range scale level does not help very deeply to understand the mechanisms and processes. In the 17th century the understanding of the blood circulation system was still at a ”medieval” level of understanding. The curiosity to probe into the empirically revealed mechanisms at display in dead bodies showed an interesting landscape of different types of ”machineries” as vessels and pumps. William Harvey’s pioneering studies of the circulation of blood in the human body were here of great importance (see e.g. the book from 1628 by Harvey: *On the Motion of the Heart and Blood in Animals*). By close observation many phenomena were revealed. Interestingly enough, what was missed was the importance of the peripheral cellular parts of the body in order to get a more thorough understanding of the drivers of this complicated system. This was left for future scientists to discover. What we see here is the way in which the interplay between the scales within a range considered to be ”meso” is at the center of the understanding.

This is of course the basis for the probing of many phenomena where the way the aggregation of the knowledge from deeper lying levels into those holding more macro significance is the central point of explanation. The Nobel Prize in Chemistry for 2003 was awarded ”for discoveries concerning channels cell membranes”. The prize winners Peter Agre and Roderick MacKinnon studied how salts (ions) and water are transported out of and into the cells of the body. The press release from the Royal Swedish Academy of Sciences (October 2003) states that, “the discoveries have afforded us a fundamental molecular understanding of how, for example, the kidneys recover water from primary urine and how the electrical signals in our nerve cells are generated and propagated… This year’s Prize illustrates how contemporary biochemistry reaches down to the atomic level in its quest to understand the fundamental processes of life.”

The classical question – and book – by Erwin Schrödinger *What is life?* (1944) was answered by himself in terms of a complex interplay of phenomena at micro levels – and best explained by physics and chemistry. This could also be said to be the standard way to relate the meso phenomenon “life” to processes and interplays at the micro level. However, there are other types of approaches possible and they cast a critical light on the scheme of reduction of explanation connecting the scale levels. In many cases the many emergent phenomena have to be understood in terms of the interplay between a bottom up perspective and that of a perspective, which analytically could be framed as “top-down”.

The late Canadian bio-philosopher Robert Rosen[A] is one among those who have tried to analyse “life” based on a different set of characteristics which could define “life” processes e.g. in a cell. Typical such functions are “metabolism” and “repair”. In his analysis about how living systems could be explained Rosen critically analysed the starting point of the machine metaphor. According to this frame of perspective organisms are considered to belong to the category of “machines” and those in turn – although ill defined – belong to the class of “material systems”.

“Von Neuman in particular came to argue that there was a finite threshold of complexity; below the threshold, we find the machines of ordinary experience which could only deteriorate – above the threshold we find machines which could learn, grow, reproduce, evolve, i.e. could do the things that only flesh is now the heir to. Crossing thus the threshold then, was tantamount to creating life; and complexity in this sense became explanatory principle for the characteristics of life.” (Rosen, 1993)

In Rosen's analysis of this way of reasoning, he pointed out that "ontology and epistemology coincide". This form of reasoning entails, according to Rosen, that an understanding of how something works also tells you how to build it, and conversely. As von Neuman put it "Construction and computation are the same thing". In addition functional activities in a machine can be spatially segregated from one another by artificial means, without loss of function. "Indeed the efficacy of reductionistic analysis absolutely requires this property; a property which we shall call fractionability … (and it) must hold ubiqutously, whether our system is simple or complex". And it is this crossing from organic epistemology to machine ontology across the presumed complexity threshold (from "complex" to "simple") where Rosen did not agree. Indeed, the move from "simple" to "complex", amounting to the creation of life, was as problematic for Rosen. The issue of non-fractionability of functions belonging e.g. to the function of a bird's wing, in the context of a flying device, point at a number of issues, where biological phenomena confronts the simple notion of reductionist explanation. In this way also the assurance of the assumed specific relation of the "standard model" between assembled micro events and a meso phenomenon appearance, breaks down, or at least needs to be heavily complemented by qualitatively new elements. Such emergent phenomena are the core of the interest by the late Nobel Prize laureate Ilya Prigogine and co-workers (see e.g. Prigogine & Stengers, 1979).

Living organisms have to survive in a complex and changing environment. This implies, among other things, to be able to respond and adapt to environmental events and changes at several time scales. The interaction with the environment, often expressed in terms of behaviour in animals, depends upon the present (dynamical) state of the organism, as well as on previous experiences stored in its molecular and cellular structures. At a long time scale, organisms can adapt to slow environmental changes, by storing information in the genetic material (DNA and RNA molecules) that is carried over from generation to generation. This is referred to as phylogenetic learning. Ontogenetic learning is adaptation at a shorter time scale. It occurs in the non-genetic structures of the organism, and this information cannot be directly transferred across generations.

At the shortest time scale, the immediate interaction with the environment is partly a result of phylogenetic and ontogenetic learning. Single cell organisms, such as bacteria and amoebas, have a rather direct interaction between the intracellular processes and the extracellular environment, whereas multicellular organisms have differentiated cells with different functions involved in the interaction.

3. Neural systems, brains and sensation: The interface between realms of existence

In animals, some cells act as sensory cells, whereas other cells function as motor cells and yet other cells connect and distribute information between the sensory and motor cells. Eventually, larger and larger networks of interconnected nerve cells (neurons) between the sensory "input" and motor "output" expand the realm of behaviour of the organism. In man the relationship between the number of sensory cells, brain cells, and motor cells is 10:100,000:1 (Maturana & Varela, 1992). It is these masses of interconnected neurons in the brain that make our cognitive functions possible; they constitute the material basis for the conscious mind.

In his book *What is Life?*, referred to above, Schrödinger, in addition to the overriding scaling issues, asks fundamental questions regarding the stability and sensitivity of our body in general, and of the brain and sensory organs in particular. He argues that our sense organs (and the brain itself) would be useless if they were too sensitive and reacted to single atomic motions[1]. Schrödinger argues, "that an organism must have a comparatively gross structure in order to enjoy the benefit of fairly accurate laws, both for its internal life and for its interplay with the external world. For otherwise the number of co-operating particles would be too small, the 'law' too inaccurate".

A similar line of arguments could perhaps be applied also to single action potentials (APs) or other events dependent on single cell activities. If we could determine the number of APs (or active neurons) involved in, say, the perception of an object, the statistical conditions discussed by Schrödinger would give the inaccuracy of that particular brain process. Reversely, if a certain degree of accuracy is needed for any particular cognitive process, one could apply the same statistical law to calculate the approximate number of events, (or neurons), necessary to be involved in the process.

Since there is continuous spontaneous activity, sometimes referred to as "noise", in the brain, it should not be "designed" normally to be sensitive to single APs, as discussed in general terms by Schrödinger. The activity of single cells appears to be largely unpredictable and noisy, but the mass of cells cooperates to produce a coherent pattern. It is the mass action of thousands of cells that make the orderly dynamics necessary for cognitive functions (c.f. Freeman[A], 1991). However, there may be situations where spontaneous neuronal events, such as the opening of a single ion channel, can be amplified, (as described above in connection to the Nobel Prize in Chemistry for 2003), resulting in an AP, that in turn can result in a cascade of neural activity. It is, however, worth noting that Max Delbrück and others, who argue against a biological relevance of quantum events, regarded such amplifications of microscopic events or fluctuations as possible exceptions (Delbrück, 1986). Another "macroscopic" effect could be, as can be shown by computer simulations (Liljenström, 1996), that noise can result in a switching between different dynamical (attractor) states. Already René Thom[A] introduced the issue of bifurcation points in the mathematical modelling of morphogenesis (Thom, 1983, 1986).

If it, in some sense, would be expected that a computer model could behave like an animal brain, one would need to incorporate the experience of millions of years of interaction with a changing environment (see also the Abisko books, Casti & Karlqvist, 1983, Haken *et al.*, and Århem *et al*, 1997, and Karlqvist, 1999). It has been argued (Skarda & Freeman[A], 1987; Churchland & Sejnowski, 1988; Haken[A], 1991) that even if the modelling efforts – in the spirit of computational neuroscience – will *de facto* produce extremely complex models that duplicate the performance of the human brain to a significant degree, the models themselves will still be hard, or even impossible to understand (in terms of some rules or principles, which relate the different parts of the system to each other and to other phenomena). This view is especially expressed by Churchland & Sejnowski (1988):

"Even if we could simulate, synapse for synapse, our entire nervous system, that accomplishment, by itself, would not be the same as understanding how it works. The simulation might be just as much of a mystery as the function of the brain currently is, for it may reveal nothing about the network and systems properties that hold the key to cognitive effects."

MacKay (1980) makes a point in that we cannot understand the human brain (or mind) at any one single level:

"If we do not choose the right logical level at which to give our description, important points may be totally missed. Understanding, as distinct from mere cataloguing, requires the choice of an appropriate level of description for the aspect that we want to understand ... Understanding the human brain can never mean building a completely detailed picture. It has to be a far more modest enterprise, carried out piecemeal by reference to a relatively minute number of sample areas of the whole nervous system ... It is important not to confuse the idea of understanding in this limited sense with the sort of understanding that could lead to complete prediction and manipulation".

In effect, this is the same as to say that we cannot reduce these aspects of (human) consciousness to electrochemical processes or computational algorithms. That would have no meaning to us, even if we claimed we had succeeded. Concepts at one level are in many cases not transferable in a meaningful way to another level. New qualities and properties emerge at each new level in the hierarchical organization of matter, qualities which are irrelevant at lower levels. Such a "holistic" view was also given by Delbrück, who compared mind with quantum reality:

"The mind is not a part of the man-machine but an aspect of its entirety extending through space and time, just as, from the point of view of quantum mechanics, the motion of the electron is an aspect of its entirety that cannot be unambiguously dissected into the complementary properties of position and momentum."

Penrose[A] (1989) brings this analogy further, believing that mind indeed may need some quantum mechanical description. He argues that there are some aspects of mind, or mental phenomena, like e.g. understanding and insight, that are non-computable in nature, and thus can never be simulated on a computer (Penrose, 1997). Such phenomena may even require a new physics, new laws and principles that are not mechanistically derivable from lower levels. With this perspective, consciousness seems to be a phenomenon that fundamentally transcends present day physics, chemistry and any mechanistic principle of biology used today.

4. The connection between nature and society: On linking apples and pears

Ecological systems may express strange time behaviours. In an article by Carl Zimmer, in a special issue of *Science* magazine (1999) concerned with "complex systems", a case of such a phenomenon is highlighted. The setting is that of the Great Barrier Reef and the case is the ecology of a small fish called "damselfish". These particular fishes lays its eggs in nests at the reef bottom. "Each month the full moon triggers the larvae to hatch and emerge; they leave the reef and 19 days later return as mature larvae". But how many of these do reach maturity? It proved to be strong fluctuations in the outcomes which were at first very difficult to explain for the researchers Dixon, Milcich & Sugihara, who studied this particular case (1999). What was searched for was the link between the number of the new adults and the measurements of the initial state of eggs at the reef bottom. To make a long story short, the introduction of nonlinear equations in the modelling opening up for feedbacks, thresholds etc provided the tools that made it possible for the "maddening dynamics" to be mirrored by only three factors, which was not possible at all by linear approaches. Now the moon's phase, turbulence around the reef and winds blowing over the water was sufficient to explain the earlier seemingly erratic behaviour. The research group stated: "From hundreds and hundreds of potential corrolates, all of a sudden three dropped out, and they made perfect ecological sense".

For us, this case not only points at the importance of nonlinear dynamics, but also at the relationship between phenomena at various levels of scale interacting to provide a specific outcome. Still another example of a theoretical framework for bridging the scales between micro- and macro-evolution is adaptive dynamics theory, which links ecological and evolutionary consequences of environmental change (Dieckmann[A] *et al.*, 2000). The theory is based on the simplifying assumption that the general dynamical and mutational time scales of a population can be separated. Analyses of special cases suggest that predictions obtained through such a method usually agree with those from more sophisticated and less simplified models.

As ecological systems evolve in both space and time, pertinent questions to be addressed include: "What spatial and temporal patterns develop in the long run, and how do these patterns develop as conditions change? How could the scaling up from the microscopic events, to the macroscopic processes, affect the full spectrum of phenomena concerning individuals to populations and to communities?" These questions become important in theoretical ecology due to the increasing use of individual-based models of spatially-extended populations and communities.

The "dynamics of patchiness" is here also a related and interesting topic. For this kind of micro-macro phenomena, applications of theoretical approaches, such as cellular automata simulations (Wolfram[A], 1984), seem to provide potentially illuminating insights. Some of the approaches in studies of ecological systems may also be applied – with care for the potential differences – in studies of social systems and human structures.

The move to combine the understanding of the natural systems with that of human behaviour and action, and thus the societal impacts, introduce still another issue connected to the "meso" discourse. It concerns the "matching" of fairly dissimilar realms of phenomena in understanding their joint behaviour, as is the case of the bio-geo-social systems.

The "grand old man" of Swedish cultural geography Torsten Hägerstrand[A] points at the problematic features of the separation between on the one side human intention and action and on the other side the geo-biospheric phenomena. Although there is a deep going difference between the two systems, still there is a profound awkwardness emerging from the institutionalized separation between these two worlds. Specifically, this holds true for the knowledge generation around these two concretely connected and interfering spheres of phenomena.

According to Hägerstrand (1996) there is a need to look for a common way of approaching the totality of the features and "forces" on the surface of the Earth. Observations and theories must be launched at an appropriate level in order to suit the needs to combine the relevant spheres of intellectual approaches. Here a combination of geographic and history traditions have to be mobilized according, to Hägerstrand.

In the *geography* tradition the understanding that the positions of all actors in relationship to each other profoundly sets the conditions for what can happen. In the *history* tradition the view is central that different processes need different time frames to be explored and that, in addition, earlier events condition what comes after. Thus the task is to bring together, according to what Hägerstrand has called (here translated from the Swedish original) the "side-by-side-ness" and the "after-each-other-ness". The challenge is to get these two characteristics – which deeply have to relate both to time and space scales – more integrativly connected to each other. "This program calls for a thorough scrutiny of spatial and temporal levels of scale that are so close to us, that we normally take them for granted and thus do not see the need for them to be highlighted". In fact they are "not known, because not looked for" says Hägerstrand quoting T.S. Elliot in *Four Quartets.*

"Whereas the architecture of the tropical rainforest is the spontanous result of the interplay between the spatial and time oriented aspects of forms during the evolution, the antidot, in terms of the high tech mega city, has been developed as a mixture of deliberate attempts to organise the environment and life and innumerable unforseen consequences."

An important feature of a combined social and ecological system is its *resilience*, as expressed by Carl Folke *et al* (2002a,b) and in Gunderson & Pritchard (2002). When such a system looses resilience it becomes vulnerable to change that previously could be absorbed (Kasperson & Kasperson, 2001). Many of these features have to be understood in terms of multiscale interplays. A closely connected issue deals with the role of diversity including the layered structure connecting different roles of organisms and their functions. In the societal management of such combined bio-social systems also multilayered governance systems have to be designed and mobilized in which the stratification of the appropriate roles to the various levels and their interplay should be outlined. This often happens as a social nested process within which political will is only one of the components in the causal chain leading to a specific setting (Svedin *et al.*, 2001).

5. On interdisciplinarity and the challenges for knowledge production

In many of the cases we have seen explored in this book – but not necessarily in all of the chapters – it has been considered necessary by the authors to "zoom in" on the phenomena of varying scales, e.g. by trying to find the "matching" between different systems with different scale characteristics. This has often called for interdisciplinary approaches. The challenge to address varying conceptual styles in the different domains of knowledge specializing on one or the other level of scale thus comes into focus. We have also seen the need to address the bridging approaches to qualitatively separated partial domains of knowledge as in the case of the eco-social example provided above.

The institutional barriers in the academic system are sometimes to be seen as a hindrance to possibilities to probe more easily some of the issues we have addressed in this book. In this sense the interest in the "meso" challenges – i.e. addressing the phenomena, which in terms of their explanation calls for the probing of the relationship between micro and macro – thus also provide a challenge to the way the generation of knowledge normally is done. The frequent lack of match between the research challenges and the institutional set up calls for fresh views and innovative reforms of the knowledge creation system. Many of the contributions to this book have had the aim, through the way the authors have handled their thematic cases differently, to point at interesting paths in addressing such challenges.

The movement towards addressing more and more "complex" knowledge objects – not seldom expressed in terms of more and more involving spans between micro and macro in the same analysis, and in terms of the break up of "easy" objects sealed off from the "disturbing surrounding" providing its context – is matched not only method wise by interdisciplinary approaches, but also by organizational patterns of knowledge generation more suited to these new traits. These challenges are addressed at length by Helga Nowotny, Peter Scott and Michael Gibbons who (2001) in their book *Re-Thinking*

Science when they dwell on many of the related challenges in the production knowledge. One of the features they contemplate already in the beginning of the text concerns “The Growth of Complexity” (p.4 and onwards). The appeal to try to address such issues is set in the context of general societal tendencies:

“The climax of high modernity with its unshakable belief in planning (in society) and predictability (in science) is long past, even if the popularity of ‘evidence-based’ research demonstrates the stubborn survival of the residues of this belief. Gone too is the belief in simple cause-effect relationships often embodying implicit assumptions about their underlying linearity; in their place is an acknowledgement that many – perhaps most – relationships are non-linear and subject to ever changing patterns of unpredictability.”

In this situation the ambition to grasp wider and wider webs of complexity, has to be matched by efforts to come to grips with many unsettled methodological issues. The ultimate drive to move into these realms has its origin in the need to grasp new phenomena of importance for general understanding, but at the same time also serving new instrumental demands. In the final end, this will provide important contributions to the creation of new aspects of culture.

Notes

[A] Connected as participant to the series of Abisko workshops.

1. According to Schrödinger, p. 8: “Because we know all atoms to perform all the time a completely disorderly heat motion, which, so to speak, opposes itself to their orderly behaviour and does not allow the events that happen between a small number of atoms to enrol themselves according to any recognizable laws. Only in the co-operation of an enormously large number of atoms do statistical laws begin to operate and control the behaviour of these *assemblées* with an accuracy increasing as the number of atoms involved increases. It is in that way that the events acquire truly orderly features. All the physical and chemical laws that are known to play an important part in the life of organisms are of this statistical kind; any other kind of law-fulness and orderliness that one might think of is being perpetually disturbed and made inoperative by the unceasing heat motion of the atoms”.

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