Nano Science: Science in Transition
A Borderline Case

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Abstract
Science is a harsh mistress. Persistently she insists on strict rules when a paper is to be written. Rarely she permits looser regulatives, seldom admits but lightly shirted pensive musings. However, the notions following describe the scientific landscape nano-sciences arise from and are born into in a leisured fashion. Nano–sciences are treated as paradigmatic phenomenon within rapidly changing scientific paradigms, the ‘turn’ to nano representing a typical example. The name indicates mathematical/ physical origin: a measure used in technology. Scientific base as well as technology application connect ‘nano’ not only to physical, but also to life systems and life sciences. Nano-sciences mean transdisciplinarity. Scientific investigation faces a borderline attempt. The implications are depicted in their essential qualities.
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1. Prologue: The Realms of Nano-Sciences

The argumentation as follows will focus on views concerning the scientific paradigm change. It will discuss, if but much abbreviated, aspects of theory of science and of epistemology in particular. The emphasis will centre on life concepts as they may be affected by the nano-sciences, as specifically nano-biology affects biophysics, biochemistry, and not least the rapidly maturing discipline of biosemiotics. Though not yet broadly discussed and accepted, the consequences likely will add to shift prevailing percepts of science. Nano science serves as a telling example for general implements of the paradigm change. For example, the inroad into the nano-domain leads to a existential as well as scientific territory, where established borders e.g. between meso- and micro-level become pervious and eventually may dissolve. Or where, in the positive, nanotechnology and photonics may amalgamate to a new physical base from which to produce low-price and efficient solar cells (Schmidt-Mende 2008).

For it must be pointed out, that nano-science emerged essentially from nano-technology, striving first for foremost technical applications. The borderline nature of the nano-domain permits notably strange physio-chemical processes. It e.g. grants to produce alloys combining three metals which are under macro/meso physical conditions not to amalgable. In addition, the alloy is transparent and can be rolled in sheets. Nanotechnology, in part also addressed as molecular manufacturing, now covers a very broad range of applications. Due to its working in the molecular domain, constraints effective on the meso-level do not hold and allow to use specific production processes as to bring forth materials with unusual qualities. But examples are 'breathing' fibres for textiles, extremely damage resistant coatings, and new medical chemicals, as to name but a few. Not least 'molecular machines' can be built by a 'molecular assembler' following the principles of mechano-synthesis (for an excellent overview see Wikipedia 'nano', 'nanotechnology'; 2008).

As the Economist puts it (Nov 24th 2007, p 82): 'The unusual properties of tiny particles contain huge promise. But nobody know how safe they are. And too few people are trying to find out'. Both safety and security may pose an equally huge threat. That is one more reason, to try to grasp the nano domain also from there peculiarities as identified from science of science.

There is another reason for a 'deep' epistemological investigation: nano-science may help to understand the hitherto opaque realms of human higher consciousness, the still latent enigmas of the physiological substrates and correlates incorporated in the CNS and in particular in the brain. Research into mini-brains (insects et alii) and surprising performances e.g. of raven birds, or into orientation capabilities pointed to scarcely explored nano-structures (micro-trabecular lattices /cytoskeletons) and their functions in the brain (Frecska 2007). To understand their function may also lead to as better scientific grasp of 'rare normal phenomena' as in Shaman practices, remote viewing or remote healing. The peculiar understanding of physio-physics behind ties to the concepts of 'endophysics (complementing 'exophysics'), understanding the world as an *interface* between, simplified, the world of the observer from *without* and the world of the observer from *within* (Rössler 1998). The still disputed approach relying on percepts in cybernetics of higher orders (as known also, in the cognitive sciences, from radical constructivism). Following the idea in (Vrobel, Rössler at alii ed.; 2008) observer perspectives and temporal structures are investigated also to their mathematical and physical correlates in nano-structures in the brain. Among others AI and quantum-computing may learn from the attempt. Science should remind here that hypotheses and even speculations, if properly handled, are necessarily part of science.

Science includes the Promethean risk: how will its consequences, epistemologically or technically, influence human life? To repeat: Security as well as safety of nano-technology need be scrutinized. So do implications of eventually hidden qualities in new e.g. ICT devices or medicinal compounds. They may well pose practical-ethical questions not easy to decide and to handle.

2. Paradigm Change

Nano-science, nano-technology and other nano-derivatives signify a paradigmatic case of science in transition. They indicate basic stances of conceptualisation rapidly changing. In particular in technology-related domains the prevailing paradigm has remained essentially Newtonian–physical. The Newtonian paradigm has been and is widely applied even when approaching life, that is 'life itself' (to borrow the title from R. Rosen) (Rosen 1985, 1991a,1991b) and life phenomena. Relational biology, a non-physical (or not-only-physical) concept, has been proposed already in the 30^{ths} of the previous century by N. Rashevsky (R. Rosen 1991a). Nevertheless the percept has been but incrementally accepted no sooner than beginning with the 1990^{ths} , encouraged by the writings of e.g. the late R. Rosen. Anticipation in particular was addressed by (Rosen J., Kinemann J.R. 2005). Recently, the strict physical paradigm often tacitly is less replaced than complemented by what can be named the 'life paradigm'. Since the topic has been discussed exhaustively in the conference proceedings, a much abbreviated comparing note may suffice here. The *physical paradigm* rests basically on the model of *particles*, particle systems having *status* and being open to *formal/material/efficiency analysis*. On that base life systems are dissected down *materially*, their *organisation* valued secondary or disregarded. (Rosen 1991a). The *'life paradigm'*, in contrast, focuses on the *elements* and their *functions* in *organisation* and but secondarily looks at the constituting matter. This conceptual frame proves useful to assess e.g. theories in the biology domain. Whether e.g. *systems biology* (H. Maturana; F. Varela, 1987) must be assigned more to the one or to the other paradigm requires a separate discussion. The concept of *autopoiesis*, though in toto perhaps a 'borderline case' concerning its degree of (in-)determinism, inclines to the life paradigm.

3. Models, Purpose and Intent

To begin with a formal reminder: Models as well as paradigms are following, are expressed by and determined by the *purpose* behind: concerning what, under which aspects etc., is to be investigated and eventually put to operational-technical use. The models base assumptions delineate the possible ranges of its *interpretation*.

A *physical model* knows but three (of four Aristotelian) causal relations: 'formal', 'material' and 'efficient'. It cannot and must not express any final causation, that is intent and purpose of the system itself as described by the model, as well as the limiting purpose contained in the act of modelling. The paradigmatic model is the *machine*. The aspect is important in particular for the *application* of science, for technology in the general sense. Restricted to physics and the machine model, *technology* so far has been defined within the *physical paradigm*. In the physical model purpose and intent are but imposed from outside by the designing engineer. Intent cannot be part of the technological set up of the machine itself. Technology constitutes the means by which a quid pro quo imposed from *outside* is realised employing *material-technical* instruments. (For the design aspect in science see also Yoshida, 2005)

Life systems (or 'viable systems' in the systems language) in contrast are determined by intent and purpose from *inside*; on the base level e.g. by survival and development. *Inherent* purposefulness signifies the *model of life systems*, that is the organisation of *functional elements entailing intent*. (Rosen R 1991b; Miller 1978; Beer 1989). An organism can be defined as the embodiment of a purpose/intent, or as its realisation. In consequence life systems cannot be sufficiently described by the physical machine model, not inhering and thus in practice discarding the life establishing *final* causation. See the cutting remark of Mephistopheles (Faust; J.W. Goethe) quoted at the end of the conclusion. Thus within the model of life systems, as described above, also *life technology* appears distinct from bare physical technology. To repeat: Life technology in essence implies elements carrying functions networked in an organisation entailing purpose and intent.

Physical sciences and physical technology access increasingly highly complex phenomena. As in micro- (and recently nano-) biology life phenomena are approached. An if silent and incremental reconciliation of pure 'physical' models concerning life phenomena proved inevitable. As above: in addition to and transgressing the physical model *functional elements*, functional networks and organisations need be encompassed. On the macro- and meso-level the insight has spawned the 'soft systems' approach concerning the societal and institutional/organisational domain, namely related to business organisations. As has been observed e.g. in *socio-physics*, connected (yet) to mainly demographic (macro-) research, physical-formal based models need organisational, intentional complements, as it latest becomes obvious in interpretation. Summing up: The limits of a barely formal/physical approach force to acknowledge the phenomena 'function' and 'organisation' and to enclose it into the analysis. The topic will embarked upon in more detail when discussing nano-biology.

4. Concepts and Measures

When for a moment leaving aside the philosophical/methodical grounding, science can be seen originating as an attempt to find answers to the challenges offered by life systems. Serving as the fundament of technology, science does so most obviously in the domain of everyday problems, the *meso*-domain (Koratayev et.al. 2006). At the same instant the philosophy behind, the beginning 'science of science', extended to the infinitely big, the *macro-level*, the cosmos, and the infinitely small, the atom, the no longer divisible 'parts' of the universe on the (sub-)*micro-level.* Modern science began with Newton focussing on the cosmos and Leeuwenhoek centring on what is not visible with the unaided eye as to integrate the views with the meso-domain of human conscious action. At the same instant, not least driven by the questions raised from e.g. alchemy roots and medicine, the central question was put anew: what is life? The answers were and are sought on all three (and extended) levels.

Focusing on the extension to the indefinitely small, recently in particular on *micro-level* technology and molecular sciences, increasingly the 'fine structure' of matter comes into focus; its particular qualities to be used in advanced technological construction. Nano- sciences and nano-technology appear but a consequence. The drive each other. And they deliver a good example concerning the overlapping of the meso-domain into the micro domain and the scaling below. Perhaps a part of the latter separately will be coined the nano-domain in its own right. It's not without interest that a mathematical magnitude, a measure - 10^{-9} m - is employed to name the domain (Wikipedia Internet 'Nano Technology' 2007).

Scarcely explored is the potential of nano sciences in connection with *biophysics*, *biometry,* with *bionics*; physiology, base life systems and their technical design applications. Bionics, abbreviated, surveys successful designs found in nature as to transfer them towards applications in technology. Membranes for desalination, sensor technology, fish movement for conveyance, eye variations for optic lenses provide but better known examples. Methodically the domain promises rewarding return, since it leads back to basic elements e.g. of movement and basic qualities of (biological) materials as tissues; chemical compounds and physical layer techniques; implying novel faculties and permitting novel constructive principles. The nano approach, in particular, carries complementary potentials to be exploited technologically, arising from its specific border line position between physics and quantum physics. Besides, the insights into the 'physics' and the 'technology' of life as pursued *micro-/nano-biology* by are fascinating. They provide new lines of constructive and striking aesthetic principles .

As to conclude, a pensive philosophical reconciliation on *measure*. Homo mensura omnium - men is the measure of all existence. The claim, if unexpectedly and in a specific implication - has been confirmed in the cognitive range in particular by (radical) constructivism. However, in technology and natural sciences, the human 'meso' realm approachable be *direct sensory perceptions* and *analogue understanding* has been overstepped and consequentially become opaque for long. The hard and the software e.g. within a notebook, or the coating of a car, need particular descriptions or metaphors to be accessible for human perception. The human sensory and perception apparatus is overtaxed. The same is valid for human cognition. The degree of *complexity* both of scientific software and technological hardware can be understood and handled but by specialists only and if recurring to complex modelling and conceptual networking. Often a simplifying recurrence to *metaphors* proves necessary. In parallel experimenting meets growing constraints as to *unmediated observation* and interpretation. Directly observable evidence is replaced by *indicator evidence.* Where experimental evidence comes but indirect as e.g. from a bubble chamber, it is often complemented if not partly replaced by proving consistency with related theories. Theory upon theory upon theory may pile up resting on but a small base of direct experimental evidence. Compliance between theories complements, but cannot replace the results of controlled experiments. Again the nano domain provides a striking example. The scale of its measures – space, time, material, complexity etc. – can often but indirectly be comprehended. That proves valid in particular when (pre-)life phenomena are investigated.

5. Life

As indicated above, science acted and acts as a means of survival and development, related to existence and evolvement. Acknowledging the arguments as above, the machine as the general paradigm of science is incrementally replaced by the paradigm of the life organism (Bateson 1979).

Life, in recent understanding, does not emerge as an evolutional hazard. Its possibility, and its *probabilities* originate uno actu with the primeval (metaphorical) big bang. As explicated above, to understand life science needs to view as well the infinitely large (as the cosmos) as the infinitely small (as Democritus' 'atom'). Early religions have acknowledged the 'necessity' of life as also the networking behind. The Hindu holy books describe it (Cooraswami; Radhakrishnan, Pantschatantra); the Egyptian papyri from Pharaoh times as found in the tombs suggest it. (King J. 2004a, 2004b, 2005, 2006a 2006b; Capra 2002). Greek philosophy as seen from the surface centred on the more formal, the abstract approach as e.g. in its early mathematics and geometry. The essential point of knowledge sought for in the abstract considerations, however, was given by life itself. Thus it seems but the closing of a necessary evolutional circle, when science if reluctantly acknowledges life as its ultimate challenge to comprehend. In this context also science of science needs reconcile its very foundations. The *analogue* logic, not Frege's formal approach describes the general case of logic. For some twenty years *qualitative research* explores inroads to the 'soft' aspects of systems. It employs analogue reasoning, describes in *metaphors*. To sum up: It is the organism, elements and function, that inheres as a base but nevertheless *special case* of the Newtonian physics. In pursue of life both complement, they network with each other.

In particular the *life sciences*, as e.g. the biological disciplines, provide a telling example. A first attempt to a paradigm change in the 50th of the previous century is connected with K. Lorenz; continuing previous research done e.g. by late 19th century biologists (see below). It has not immediately been pursued to its full extent. In the decennia following the re-consideration of the concepts of *evolution* occupied the main energies in research. So did the rapid rise of *micro-biology* exhaust the research capacities centring mainly on a basically physical approach to life on the cell level. The results have been and continue to act seminal. But they also abundantly corroborated, that life cannot be explained by physical/material concepts solely to scientific satisfaction. That holds true clearly on the macro- and meso-physical, the roughly Newtonian level. *Nano-biology*, the fast developing next phase in biological research now on the molecular and (here 'physical') element level, faces, on the one hand, the identical limitations of a physical-formal approach. Naturally it has to be resolved in which way following which rules certain elements, molecules, prions etc. connect and structure. On the other hand, nano-biology has to ask *why* they do so, following which constraints, which rules, which formula *entailing the intentions* and the *probability fields* of the systems resulting (Nalimov 1985,1989). Any notion of a vis vitalis (vitalism, H. Bergson) can be discarded; it does not scientifically explain, at best helps clarify what has not yet been explained and needs be so.

To explain life phenomena *quantum physics* have been summoned very early. The quantum world, extremely simplified, displays, in the view of macrophysics, strange qualities. It shows strange behaviour and leaves open phenomena as well as evolvements within different domains of probability, causation and so on. Might these conditions give rise also – and again necessarily, unavoidably, to direction, meaning, purpose? To intent as observed in life systems and as crucial in evolution from pre-life forms to higher consciousness? The ongoing dispute (see e.g. biosemiotics; Barbieri, 2008) argues increasingly also on the nano-level. Does under this approach the nano-level qualifies as a domain where physics and quantum physics meet? overlap? build interfaces? permit ambiguously interpretable phenomena? May they eventually lead to dynamic evolvements, in detail not determinable, but in result 'directed'; interpretable as pre-driven, pre-governed, or attracted by however strange attractors? It seems, for example, that in the nano-domain even matter belonging to the macro-sphere may exhibit quantum behaviour. However, even if this is still and will probably remain quicksand, nano-sciences open new vistas to understand life comprehensively, that is from a transdisciplinary stance (see below).

In particularly related to this context nano-sciences are closely coupled with *non-linear mathematics,* respectively with *chaos* and *complexity* theory(ies). The theories can be but noted here in a summarizing fashion, that is as a research approach close to the physical- chemical side of nano-sciences. *Anticipatory computing* as a discipline founding and complementing anticipatory phenomena in life may serve as an example (Dubois, 2001), as life phenomena are seen here from the biological stance. Anticipation as a precondition for life systems for example by anticipating changes in environment as to adapt to e.g. seasonal changes, in time not to be harmed, has been explored recently in detail by J. Rosen and Kineman (Rosen J., Kinemann J.R. 2005). Closely linked appears the notion of *'relational causation'*, that is (adaptive, directed ?) causation determined by the state of a life system and of its functions. Another key phenomenon appears that of *pre-adaptation* changes.

Such a proposal rises fundamental epistemological questions. Why and quo modo do life units seemingly purposefully act, adapt anticipatorily and do co-act with their inner and outer environments in an intent driven mode? The question aims at an answer re-instating the Aristotelian *'final causation'* to the life domain. Physical concepts acknowledge so far with good reason but 'formal', 'material' and 'efficient' causation, refuting 'final' causation. In the physical/formal apparatus any *causa finalis* is by nature of the accepted physics concept excluded. Life systems in contrast, as shown above, rest on the anticipatory qualities of their control systems connected to purpose and intent. It can be argued that this implies final causation at the systemic base. The challenge was met and at least partly resolved by very different if related concepts from various disciplines. Stimulated by the insights of scientists as different as Th. Seboek [zoosemiotics] (Cybernetics and Human Knowing. CybHKn 2003); R. Rosen [Relational Biology] (Rosen 1991b), Ch.S. Peirce [Sign Theory] (Peirce 1969). Further promoted also by other biologists, linguists, philosophers, science theorists and cyberneticians, *biosemiotics* was born.

[Note: Biosemiotics interprets communication between biological entities as sign and language systems. They explore the emergence and the role of *meaning* in life and evolution. Biosemiotic research resumes attempts from the end of the 19th Century (R. v Uexküll; 1956) and biologists in the first half of the 20th century, focussing on the co-action of life systems with their environment.]

The understanding of living systems implying biosemiotic concepts needs recourse to nano-biology. That is the case in particular when it attempts to interfere with live systems , e.g. when trying to 'design' and to 'facture' life (-like) systems following intentional, model supported physical-chemical construction principles. For example nano-chemistry sets on to design medicaments following set targets. The intent concerns the restitution of 'health' in complex life organism, its elements and functions. To realise it needs the complement of barely chemical techniques with biosemiotic principles. Not by chance the argumentation touches the ongoing discussion relating to a more sustainably effective 'holistic' medicine, understanding the organism not as an however complex machine (LaMettrie) but as an organism within the concepts of biophysical, biochemical and biosemiotic sciences. All those endeavours need extend micro-biology to nano-biology.

6. Epilogue: Transdisciplinarity Quested

Nano–sciences are indispensably connected to life. That holds true for their conceptual base as well as for their application in nano-hyphen disciplines. The investigation on nano levels needs by nature be transdisciplinary as to be able to integrate different disciplinary fundaments. (Loeckenhoff 2004, 2006). A shared language, a shared set of models and of common methods are to be established. Transdisciplinarity needs meet particular challenges when life systems are implied. Nano-sciences constitute such a case. Even if originally attached to physics, they extend to life systems. In consequence physical models have to be completed and integrated with models from life sciences. Why this is so, which challenges are to cope with, and where a tentative solution may be sought for has been shortly discussed above.

It can but be addressed here, that the venture 'transdisciplinarity' presupposes a reconciliation of the very foundations of *science of science*. Several scientific endeavours carry hidden or openly the demand for a paradigm change. To repeat but those addressed above: they are systems theory, in particular systemics and general systems theory; biology; (bio-)semiotics. They follow the recent 'turns' in science, as the 'evolutional turn' or the (bio-)'semiotic turn'. Among these, the *'information turn'* expressively spawned attempts to redefine science in terms of *information*. As most advanced qualifies the somewhat extreme approach of T. Yoshida (Yoshida 2005). 'The Second Scientific Revolution in Capital Letters –Informatic Turn`, as his paper was titled, proposed what he called a neo-meta-paradigm. It distinguishes 'cognitive sciences' from 'designing science' (engineering). Under the heading of 'evolutionary information' he discerns 'semiotic' and 'non-semiotic' information, thus opening the door to a comprehensive understanding of the world from a set of networked specific concepts of information. Of interest appears in particular the closeness if different relationship to concepts from relational biology and biosemiotics.

The quest for transdisciplinary concepts is but at its beginnings. Conceptual as well as practical technological scientific- technological attempts as nano-sciences underline its importance and urgency.

Who wants to describe and recognize life
First tries to expel the spirit away
He then has all the parts at his hands
Lacking, alas! the spiritual bond

Goethe ‚Faust'
Author's free translation.

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