PART 1

WHAT IS NEGATIVE ENTROPY? FROM WORLD VIEWS TO BIOENERGETICS

What an organism feeds upon is negative entropy. Or, to put it less paradoxically, the essential thing in metabolism is that the organism succeeds in freeing itself from all the entropy it cannot help producing while alive.

Erwin Schrödinger: What is Life?

Erwin Schrödinger around 1902

ERWIN SCHRÖDINGER'S WORLD VIEW. THE ROLE OF PHYSICS AND BIOLOGY IN HIS PHILOSOPHICAL SYSTEM

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PHYSICS, BIOLOGY AND PHILOSPHY

Erwin Schrödinger is well-known as one of the greatest figures of theoretical physics. He became famous for his mathematical formulation of atomic dynamics, known as the Schrödinger equation, and its application to atomic structures. In 1933, he received the Nobel Prize in physics (jointly with Paul Dirac). It therefore comes as no surprise that interpreters of Schrödinger's work, dazzled by his genius and the results he obtained in quantum physics, almost forget the other Schrödinger, the biologist and philosopher. In reality, he not only revolutionized the foundations of modern physics but also made significant contributions to biology and the philosophy of science [1]. The paradigm change he initiated has had great consequences for the natural and social sciences, the humanities, and our present world-view in general [1,2].

It is not so well-known that there are such powerful principles behind Schrödinger's wave mechanics, such as his dynamic view of matter and his holistic view of nature. Such views mark the beginning of our era of dynamic sciences and our new dynamic world-view with its ongoing synthesis of quantum physics and quantum chemistry. In his book *What is Life?*, Schrödinger tried to integrate quantum physics and quantum chemistry with genetics and evolutionary biology [3]. His dynamic view of the evolution of life has led to the present breakthrough in the biology of evolution, to the greatest intellectual adventure in the history of science and culture: the deciphering of the genetic code, followed in the next decade by the deciphering of the human genome. The latter development will give rise to a new, scientific meaning of Socrates' "Know thyself". The dynamic concept of evolution has had a strong bearing on today's unified theories of the universe, such as the GUT theories. With these theories we are able, for the first time in history, to explain the origin and evolution of our universe and the beginning of self-organization in the life of civilizations and cultures. The final theorization of these dynamic evolutionary processes would not have been possible without Schrödinger's pioneering work.

One consequence of this new outlook is the present integration of natural sciences, biology, sociology, and even religion and culture in a new science of life and of evolving societies.

FROM SCHRÖDINGER'S CAT ...

As soon as Schrödinger's wave mechanics appeared in print, a pandora box of problems and paradoxes was opened, one of which was the famous paradox of Schrödinger's cat. Schrödinger's thought experiment of 1935 demonstrated the paradoxical consequences of quantum-physical indeterminacy for macroscopic reality. Schrödinger was a cat lover; and Schrödinger's experimental cat was, of course, an imaginary cat in an imaginary experiment. Nevertheless, this cat almost shattered quantum physics. Even today, this imaginary experiment challenges us to decide between its two possible solutions concerning the cat's reality after the

animal has been locked up in a container for an hour. Schrödinger illustrated the role of chance for all dynamic and evolutionary processes as follows: the cat's existence depends on a random event (radioactive disintegration) which has a 50% chance of occurring (higher than in atomic incidences). After an hour this results in the following paradox: the cat is in the ghostly, paradoxical situation of being 50% alive and 50% dead - a state equivalent to the indeterminate one of microparticles in their atomic environment. But the cat can only be either 100% dead or 100% alive.

This experiment places Schrödinger between the most famous controversy of the twentieth century, the one between the Copenhagen school on the one hand, and Einstein, Rosen and Podolsky on the other. It is well-known that the controversy revolved around the interpretation of quantum theory and the new holistic features of reality which tie the observer to the observed system. Schrödinger himself was the first to give a paradoxical description of a macrophysical body solely in terms of microphysical properties, i.e., by the ψ function. He felt uneasy about the consequences of his dynamic theory and its hidden holism: a subjective quality or activity of human beings, for example, observations, measurements, the semantics of their languages, or their consciousness can influence nature's physical state.

This is part of the intellectual heritage which Schrödinger bequeathed to physics and modern science as a whole; it did not die and perhaps never will. It remains a challenge to us since it marks the transition from old and established concepts to new ones. This paradox always surfaces, when new thoughts about reality clash with the views of a scientific community which did not have the courage to debunk the old, traditional views.

This is exactly what happened to physics as soon as Schrödinger's wave mechanics, a new dynamic model of matter, appeared. It unleashed a world-wide dispute regarding its foundations and consequences. It brought up again, for example, the old nagging question about the reality of our external world. Could the familiar, millennia-old Aristotelian concept of an underlying, unchangeable substance, *e.g.* the atom, be abandoned in favor of Schrödinger's new dynamic one where "substance" resembles a bundle of waves or melodies? This, at first, seemed impossible. Indeed, Schrödinger's turn to a universal dynamics can be seen as unsettling: change is now the main characteristic of reality. That is to say, nature and society are actually in a constant state of flux and disturbance. This makes it very difficult to explain how order and stability came into existence and can coexist with randomness and chaos. Precisely this is the crux of Schrödinger's philosophy.

... TO THE EVOLUTIONARY DYNAMICS OF LIFE

His views, in turn, have led his adherents to the evolutionary dynamics of life in our cosmos, to the self-organization of order. They also have had consequences for the revolution of societies, technologies, sciences, and cultures.

Schrödinger's philosophy was a personal one, a fight against traditional ideas: proceeding from mathematics and quantum mechanics to thermodynamics, to biology, and finally, to philosophy. His ideas, in fact, continue to influence our present theories about the evolution of the cosmos, of life on earth, of consciousness, and culture. They underline man's responsibility vis-a-vis science, technology and even evolution.

To understand Schrödinger's controversial, even polemical ideas it is

necessary to grasp why they had such an impact on his contemporaries, on today's philosophy of science, and on our modern world-view. His ideas were, as he said in his address to the Prussian Academy of Science in 1922, "*a result obtained from a lifelong love of science*."

Schrödinger's thinking unites the holistic view of wave mechanics and the dynamics of living beings, individuals and culture and anticipated developments in practically all of modern science. In brief: we first have to understand the world, the sciences, and culture as a dynamic and interdependent whole. This basic insight then led Schrödinger, and anyone who reads him closely, to new views of central problems of philosophy and life, reality, the mind-body problem, the nature of the ' I' and of consciousness, and to a new answer to the question of the meaning of life. But if we really want to follow Schrödinger, we have to be willing to free ourselves, just as Schrödinger did, from the fetters of our traditional, exclusively discursive European way of thinking. The East seems to provide a more intuitive and holistic approach, one which could ultimately be adopted. Schrödinger liked to compare Western and Eastern philosophy with the idea of split brains. The left side of our brain perceives the world in a linear, logical, and rational way, and can be seen as corresponding to the yen of Chinese philosophy. The right hemisphere perceives patterns as a whole, it works intuitively; and it corresponds to the Chinese yang. It seems that Schrödinger's philosophical convictions and his new holism can be illustrated by the following idea: in spite of the fact that both hemispheres work in a different way, they cooperate when thinking and solving problems.

Rupert Riedl [2] is fascinated by the fact that Schrödinger was both a physicist and a biologist. He is convinced that only future cooperation between physicists and biologists can help us to successfully continue Schrödinger's quest for a final answer to the question '*What is life?*'. Schrödinger may have overemphasized the role of entropy and order, while neglecting the concept of free energy and energy exchange between evolving systems and their environment. It is the latter concept which is becoming more and more important for all life sciences and life on earth as well.

OPTIMIZATION BETWEEN CONSERVATION AND DISSIPATION

How can a biologist explain the dynamics of evolution, the self-organization of life and the relative stability of all living species? If biological order is understood not only as dynamic but also as evolutionary, it is much easier to explain it in terms of equilibrating energy-conservation and energy-waste between living systems and their environments than by the concept of order [2]. This energy concept has been formulated recently by Prigogine. Together with the function of hierarchical structures of organisms and the role of information for living organisms, it complements Schrödinger's view. For the first time, we are now able to explain the evolution of the world from primordial chaos in terms of the increase in storage capacity for genetic information and instructions concerning the self-organization of higher forms of life and ultimately of social systems.

If we fail to learn from these ideas, as for example how to equilibrate energy exchanges between humans, other terrestrial living systems, and their environments, we will inflict economic and socio-cultural destruction, environmental catastrophes, etc. on our planet.

For Schrödinger, the genome turned out to be an order-preserving, negentropic empirical factor; it represents, maintains and regulates the highest

form of order on earth. At the same time, genes are a monumental codified, intersubjective memory of life's past on earth; they determine, albeit in a statistical sense, present and future evolution. Genes guarantee epigenesis, growth, metabolism, replication, and the relative stability and self-identity of living organisms throughout their lifetime. Genes are also the codified seat of Schrödinger's higher laws; they are superimposed on physical laws and cannot be reduced to the ordinary laws of physics.

As we have already seen, genes regulate not only the metabolism, the construction of our body and our brain, replication, and our basic social behavior, they also maintain the self-identity and stability of the ego, or what our Western philosophy and religion calls "the soul". Thus the self-identity and stability of individuals is encoded in, and guaranteed by, our genes; but self-identity and stability are relative since they last only as long as the individuals live. Schrödinger's concept of negentropy and Prigogine's nonequilibrium theory anticipated the evolutionary stability of organisms.

Schrödinger's introduction of the concept of an order-preserving genome into biological evolution leads right up to Maynard-Smiths' stochastic theory of evolution, the former being the missing link between the modern theory of evolution and Darwin's theory. It is no wonder, then, that Schrödinger foresaw as early as 1944 that quantum physics and chemistry would merge with biology and genetics. The result was to be a comprehensive new scientific theory of evolution which would change our view of man and nature.

Schrödinger's ideas have helped form the cornerstone of a new science of the evolution of life, man, society and culture. This new science offers solutions for problems such as: How does living matter evade decay or entropy? What is the past and present role of hereditary substance and the genes? What is the nature of consciousness? Why is our will free? Should mankind take socio-cultural progress into its own hands?

CLASHES IN THE WAKE OF UNIFICATION

To illustrate the unity of body, mind, and consciousness, Schrödinger borrowed holistic ideas from the East. But to his own amazement, he discovered that his new holistic concepts clashed not only with Western thought but also with the fundamental laws of traditional Western science.

Nolens volens, Schrödinger became the father of all those scientists and philosophers who have tried to integrate Eastern holistic solutions into the "Lord's quantum mechanics" - as he himself said in 1948. But he also suggested that this Eastern holism could be adopted for solving problems, *e.g.* world-wide pollution, deterioration of our planet's climate, nuclear energy, etc. Schrödinger's ideas are also relevant for the unification of East and West which will unite a multitude of cultures in a future world culture. It becomes more and more evident that we cannot rely on the competitive way of thinking of the West.

If we read Schrödinger closely, we will see that the greatest hindrance to understanding Schrödinger is not his new ideas, but our reluctance, or even inability to give up received views and traditional concepts. It is thus no wonder, then, that Schrödinger's revolutionary views and his criticism of traditional thoughts were suppressed and persecuted by the Nazis. (Schrödinger left Berlin in 1933 shortly after Hitler came to power, and Graz in 1938 when Austria became part of the Third Reich). As a result of German politics Schrödinger's philosophical works disappeared from public consciousness in the German-speaking countries. The

immense progress of physics, biology, and social science today shows that his revolutionary philosophical ideas were topical. Schrödinger can be regarded as the spiritus rector of the present turn in our modern scientific world view; his ideas have triggered a revolution in today's philosophy of nature and philosophy of mind, in biology, psychology, and recent ideas in the social sciences.

Quantum mechanics was the first genuine "theory of change". Its assumptions about dynamic structures are of prime importance for our century because modern cognitive science appropriated this "dynamization". Schrödinger's wave mechanics broke with the traditional, orthodox static view of reality. There is an inherent conflict between Schrödinger's objectivation postulate (his reality postulate), Schrödinger's own wave dynamics and our common sense understanding of nature and causality. Schrödinger saw very clearly that his new foundations of physics would sooner or later clash with our traditional views of the world and lead to a philosophical gigantomacy vis-a-vis the reality of our world. In a nutshell: Is nature a state of constant flux or is there such a thing as never-changing objects? This conflict could not be solved within the field and by the means of physics and even went against the grain of all traditional physical laws. In particular, Schrödinger's concept of inseparability (holism), his concept of objectification, his substitution of deterministic laws through statistical laws are still topical today - ideas which force us to abandon our classical lines of thinking. These changes induce new epistemological and ontological paradoxes, uncanny follow-ups of the cat paradox.

When he defended his own wave mechanics and its statistical interpretation, Schrödinger opted for neither the pros nor the cons of his theory. Being a meticulous and modest scientist, he turned to contemporary physicists for help. And there is yet another rift: the mathematical, deterministic nature of Schrödinger`s wave equation as opposed to its indeterministic, statistical interpretation. Schrödinger also liked to think "metatheoretically" about theories in terms of classical "either-or" categories. This either-or approach made it possible for Schrödinger to make a clear choice between the alternatives, *i.e.* either to accept all the consequences of his own wave mechanics, including its new and strange holistic world view, or to stick to Einstein's classical, traditional world view. These discrepancies resulted in alternatives which continue to plague quantum theorists today. The reader can opt for either of the following:

(1) We can picture and represent our reality, as in the classical sciences, which includes, of course, Newtonian physics, or we can describe reality only statistically and mechanically and cannot represent it in a "pictorial" way, as in quantum physics. *(2)* We can describe things and their changes precisely in a local space and time, as in the classical science or we can observe the behavior of subatomic particles only statistically (indirectly and imprecisely), as in quantum physics. The latter can be applied to the behavior of individuals in a society as well. *(3)* We can predict individual events, as in the classical science, or we can predict frequencies, probabilities in group behavior, as in quantum physics. The latter option can be applied to the social sciences. *(4)* We can assume an objective reality "out there", as in classical physics and the classical sciences, or we can say that there is no objective reality that is totally detached from our experiments and observations, as in quantum physics. *(5)* We can observe and measure something without changing it, as in the classical sciences and in everyday life, or we cannot observe anything without changing it, as in quantum physics. *(6)* We can agree with the classical sciences that "absolute truth" is possible and that, in keeping with

Einstein's view, physics describes nature as it really is, or, we can say that there are only dynamic relations which we express in terms of statistical correlations between events, individuals, etc. "behind the scenes", as in quantum physics.

COOPERATION VERSUS COMPETITION

When confronted with these alternatives, Schrödinger chose to follow neither Boltzmann, Einstein, Rosen, Podolsky, etc., nor any of the "Copenhagen" physicists Bohr, Born, Heisenberg, etc. In this greatest scientific debate about reality and the foundation of our knowledge of the world, he positioned himself between the two antagonistic groups.

The foundation of quantum physics and the new scientific world-view were actually more a result of a creative cooperation than of the usual competitive fight among scientists. Schrödinger, when asked by a Viennese philosopher about his position and attitude in the Einstein-Bohr dispute, answered: "I tried to cooperate with them." He liked to compare his position with Plato's stance in the Greek dispute about the interpretation of reality. For Plato, this dispute resembled the mythical gigantomacy, the deadly fight between the giants and the gods. Like the Einstein-Bohr dispute, the Greek philosophical dispute was fought between two schools, the Eleatic metaphysical philosophers (Parmenides, Zeno, Pythagoras) and the Milesian empirical philosophical school (Heraclitus, the sophists). The latter - the so-called "panmovers" - conceived of the universe as eternally changing, as being in a constant flux. Only change was real for the panmovers. Their position is reflected in an idea which is gaining ground today even in the social sciences, namely that nature is largely governed by flux, disturbances and chance. For the Eleatic philosophers, change did not really exist; the "real" reality behind change was seen as unchangeable.

The explosive development of quantum physics in Schrödinger's time was based on the close cooperation of a whole group of scientists despite their divergent opinions. Thus, the new physics, the new revolutionary knowledge and world view were born from cooperation, something unheard of before in history of science. It may be seen as significant for our culture that cooperation effected more than the usual fierce, competitive fight for personal superiority or for the glory of academic institutions.

EXTERNAL AND INTROSPECTIVE WORLD VIEWS

Most interpreters see Schrödinger as the architect of our modern "external", scientific world-view. This is simply because the objective bent of his scientific view of our world has been discussed widely and is accessible to all of us through books and libraries. But this is only one side of his epistemology. Schrödinger, the scientist, whose profession was to supervise the construction of the new foundation of our objective, external view of nature, quantum theory, became more "introspective" in his later life.

Most characteristic for Schrödinger the scholar was his tolerant, but at the same time critical philosophical attitude, even towards his own quantum mechanics. When Schrödinger cast his teacher Exner's dynamic views into the mathematical form of the famous Schrödinger equation, he became immediately aware of the change he had brought about in the conceptual and formal foundations of classical physics. Schrödinger was convinced that this change would sooner or later spread to the very fundamentals and methods of all cognitive sciences, in the same way relativity theory had changed our classical views about

space and time and traditional cosmology.

He remained sceptical about the validity of any possible consequences which could not be empirically tested. For Schrödinger, science should always be open to empirical tests. As long as its results cannot be confirmed or rejected, it is not a cognitive science.

As historian he not only wrote a book called *History of Greek Philosophy* but also always analyzed the results and views of his predecessors in their historical contexts. Schrödinger also saw a close relationship between physics and history since both deal with indeterministic and irreversible processes which cannot be explained by deterministic causal laws. This is quite contrary to Einstein's view.

On the one hand, Schrödinger was deeply influenced by certain rational, empirical views which he found in Vienna's academic circles (Exner and other scientists). On the other hand, his own views may be linked to those of the "uprooted" poetic and intuitive Austrian cosmopolites and the "fin-de-siecle" prophets like Kafka, Kraus, among others. Schrödinger always tried to bridge the gap between these two Viennese cultures. Their marriage was to give rise to a new world view, a new humanism beyond rationalism and traditional humanism. For example, since both "cultures", as well as all empirical sciences, are governed by statistical laws this would guarantee all individuals a relative leeway and freedom within democratic societies.

Schrödinger saw very clearly that free will and ethics cannot be subjected to either deterministic laws or the whims of physical chance events. His more introspective views, with his explanation of how individuals acquire their personal world views, were influenced by Schopenhauer and by the Indian Vedanta philosophy. Here he was convinced of the following: whatever we know about the world, be this knowledge scientific or prescientific, is mirrored solely in our sensations, perceptions, memories, and, of course, our language. The latter acts as the big mediator and social communicator in our culture. To be conscious of something, then, means nothing other than something being mirrored in such a way.

UNIQUE AND CONNECTED

By necessity, Schrödinger touches on the problem of metaphysics and nonscientific experience. For Schrödinger, anything concerned with the supraphysical is metaphysics. Metaphysics transcends science; it may complement our world view, provided it does not contradict science. Metaphysics should fill the gaps in our world view which are not yet filled by science. This is one of the reasons why Schrödinger used Indian Vedanta philosophy to support his scientific views and to make them more plausible, as, for example, in his theory of how we gain personal knowledge of our world and then integrate it into our individual view of the world.

He actually unravelled the problem of the ego and consciousness with only minimum recourse to metaphysics (if one assumes Vedanta philosophy to be metaphysics). Schrödinger started from his quantum-physical explanations of the interaction of the genes with the body and the brain. Based on this explanation, he developed a full theory of the cognitive mental process of how the 'I' synthesizes our knowledge of our world into an individual world view. He used a physiological cognitive model to explain the interaction of brain and 'I' and the concept of cultural-linguistic mediation to clarify the interaction of the ego and the social community.

According to Schrödinger's holism and his cognitive explanation of our

individual process of knowing, the external world - even though it exists out there independently - and my consciousness cannot be separated. First, we are physically connected with the external world through our sensations. But the external world appears to me and to my consciousness only as my sensations, perceptions, memories, in brief: as my mentifacts. Second, since only single data, individual information, enter via our sense organs, our consciousness, the full inner picture has to be constructed and synthesized by my cognitive, mental functions. These perceptions, sensations and memories can only be connected and ordered through our imagination and our memory: this is our inner world-view. It makes no difference whether we do this with the help of scientific knowledge, mystical insights or even prescientific beliefs, as long as we verify or confirm our inner picture through empirical reality. Since this comes close to the views of Indian Vedanta philosophy, Schrödinger deliberately uses its liberal epistemology to support his introspective model of cognition.

In both versions, my personal world view exists only as my inner mental construction, as representation or combination of sensations, perceptions, memories, concepts, and mentifacts, ordered and woven to form a unity through the activity of the 'I'. Schrödinger shows why Western philosophers encounter almost insurmountable problems when dealing with such topics. If my world is my mind's individual internal representation of the external world, then it is finite; the world ends for me with my death. Therefore, for Schrödinger and the Vedanta philosophy, my 'I', or the assumed substrate called "soul", cannot be immortal. Since my world picture is my internal, unique, singular view of the world, we cannot say much - and perhaps nothing - about the world pictures in another 'I' or consciousness.

According to Schrödinger, there is no plural for expressing the uniqueness of my 'I' and for my consciousness. But then how does Schrödinger explain how common and individual world view interrelate? In Vedanta philosophy, each single individual is just slightly different from the other individuals. Likewise, Schrödinger thinks that the similarity between the individual human genome (the genes in the gene pool) guarantees that the different pictures of reality in each 'I' or individual are similar, in the sense that they are only slightly different facets or different copies of the same external objects. This 'I' or consciousness cannot be directly transferred to others. This is only possible indirectly via language in a way that does not interfere with reality.

This is how Schrödinger reconciles the individual world view with the scientific one. Both should be subjected to verification procedures. His solution avoids many paradoxes, one of them being the paradox of free will. According to Schrödinger, moral laws are the expression of mankind's biological, evolutionary transformation from egoistic to altruistic, cooperative beings.

Schrödinger's new evolutionary concept of world view ultimately brought the physicist in opposition to the official Nazi-philosophy of his time. The drastic change in man's view of the universe and his world shook physics and philosophy in the thirties. It was the disappearance of the harmonious unity of man and world, the legacy of Greek and European thinking, the reevaluation and the transformation of the classical world, based on Schrödinger's new dynamic concept of nature. Here nature is understood as an evolutionary process, in which man is no longer an onlooker but an active player.

While Schrödinger's new world view was no longer compatible with the traditional static understanding of the world, it was also not sufficiently reflected by

our modern scientific knowledge of nature. Schrödinger engaged in a lifelong search for a new "metaphysics" which was not to be found in either metaphysics in the traditional sense or in just scientific progress. With man and nature becoming emergent components in the self-organizing process of our culture, scientific cognition is central to Schrödinger's new world view. Any increase in knowledge of nature thus corresponds to an increase in human self-understanding with cognitive science becoming the most powerful weapon against any kind of metaphysical, speculative world view. Schrödinger's reevaluation of traditional metaphysics can be seen as a modern synthesis of knowledge and man's understanding of himself. Scientific knowledge is based on invariance or symmetry, not on an idealistic, epistemological concept of subject vis-a-vis inalterable objects.

According to Schrödinger, the scientific progress in man's view of the universe and nature stipulated a new dynamic unity between nature and culture. In his world view man is part of nature and cannot be reduced to physics or chemistry, since both cultural evolution and biological evolution are parts of a common, irreversible and non-linear evolution. In the new philosophy and in Schrödinger's new world view, subject and object relate to each other in an evolutionary way. Here the physicist anticipated the central idea of today's cognitive science: there is no longer a separation between matter and mind, subject and object, brain and consciousness.

Man is also no longer seen as an isolated part of the world. Like nature he is guided - albeit in an indeterministic way - through a process of universal evolution. Man and nature do not coexist but co-evolve. In this sense we have to understand Schrödinger's bold claim that scientific cognition of the world becomes self-knowledge. The integration of knowledge of nature into the dynamic network of a dynamic culture culminates in ethics and morality, in spite of the fact that morality cannot be reduced to science. The thinking subject is no longer just a linear extension of scientific reasoning but an active part of the approximation between culture and nature.

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