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GENERAL SYSTEMS THEORY

An Introduction

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Preface

As a lecturer in Sweden working within the area of informatics and systems science I have many opportunities to present and recommend international papers and literature. This task is especially stimulating when I act as supervisor for my final-term students as they prepare their degree theses. However, both my students and I are aware that the suggested books are for the most part hidden in some far-off university. The few books that are to be found in the local bookstores and libraries are devoted mainly to the presentation of a single theory and give only a hint of all of the many other theories.

I therefore embarked on the task of presenting a summary of the most prevalent systemic ideas and concepts, well aware of the importance of facilitating access to contemporary theories, especially for those students preparing their theses. In the early phase of this work I also became aware of the lack of easily accessible introductory books within the area. My original intention had then to be revised so as to allow for a presentation of at least the most important subareas of the somewhat dispersed knowledge in informatics and systems science. One of these subareas is information and communication theory. Another is cybernetics, which today is part of General Systems Theory and is defined as 'communication and control in man and machines'. The need for knowledge about basic concepts in information and communication theory is obvious here. This and other main knowledge areas related to systems theory are therefore presented in their own chapters.

Although the selection of theories for this book is inevitably subjective, I hope that my years as a lecturer have given me a reasonable feeling for what should and should not be included. While the following pages are written for students of systems science, they should also appeal to students of related disciplines who want to examine the relevance of this field of knowledge to their own specialism. My hope is that the contents of this book will also offer something of interest for the general reader.

Do we really need system theories? Their claim to be part of a universal science has evoked criticism: a 'theory of everything' has no real content and must of necessity be superficial. However, to be honest, the attempt to gain more abstract and general comprehension must sometimes be made at the expense of concrete and particular exposition. But it is also true that the most general theory, which explains the greatest range of phenomena, is the most powerful and the best; it can always be made specialized in order to deal with simple cases.

The why and how in defence of Systems Theory is presented in the following chapters. When applied sensibly, this theory will make us conscious of the far-reaching interconnections and complexity of our existence. It will show the consequences of adopting solutions that are too spontaneous and too simple and should help us to speak in terms that are understandable in fields as removed from each other as agriculture and astrophysics. Furthermore, it should be recalled that systems theory and its applications emerged out of a need to solve real world problems.

All who attempt to solve problems, make recommendations and predict the future, need theories, models and, as a starting point, concepts, which represent the backbone of the task. Theories introduce order and meaning to observations that may otherwise seem chaotic. Good theories should provide a simplified presentation of complex ideas by establishing connections between hitherto unrelated phenomena. They enhance a growing understanding and help us to guide future research. Those searching for useful ideas among these pages must however realize that the benefit of a certain theory has nothing to do with whether it is 'true' or not – 'truth' is a quality that is undefinable. What we can define is usefulness in relation to our need; different needs obviously demand different theories.

To students asking for a definition of what a good theory is, I recommend the following uncomplicated 'theory'. A good theory is a model that helps you to explain in a simple manner what you are striving to achieve. More scientifically, a theory may be defined as a model concerning our inner or outer environment (or most often a part of it) and some rules which relate entities in the model to observations of reality. The theory can be seen as good if it both satisfies a careful description of a large amount of observations based on a few arbitrary elements and makes reasonable prognoses of future situations. Nearly always, simplicity is the mark of the good theory. But beware – there is no way to prove that a better theory does not exist.

What has not been explicitly written in the chapters of this book, but possibly can be 'read between the lines', is quite naturally a main concern for the author. That this regards a world view where human existence is not guided by a blind faith in computer 'fixes' and 'big' science will, it is hoped, be understood by the observant reader. If the reader feels comfortable with the theories and approach of this book, he or she is running the risk of becoming involved. Any such involvement will further enhance the meaning of this venture.

Finally, I feel compelled to confess two misjudgements when this book was planned: underestimation of the work effort involved and overestimation of my own working capacity. Without these misjudgements this book would never have been written, an experience no doubt shared by many authors. So now the book exists; whether for good or ill can only be judged by the reader.

Lars Skyttner
Helgeåkilen 1995

Part 1: The Theories and Why

1 The Emergence of Holistic Thinking

- **The scholastic paradigm**
- **The Renaissance paradigm**
- **A mechanistic world view and determinism**
- **The hegemony of determinism**
- **The age of relativity and quantum mechanics**
- **The systems age**

'Reality is not only stranger than we conceive but stranger than we *can* conceive.' (*J.B. Haldane*)

While man and his situation are the central focus of all social and humanistic sciences, each science pursues its studies from a certain point of view. Political science concentrates on the society's political and administrative organization. Business economics are concerned with the commercial organization, geography with the physical structure and philosophy with the pattern of thought, views of life and ideologies, to name some examples.

Systems science too has its specific point of view: to understand man and his environment as part of interacting systems. The aim is to study this interaction from multiple perspectives, holistically. Inherent to this approach is a comprehensive historical, contemporary and futuristic outlook.

Systems science, with such an ambition and with its basic Systems Theory, provides a general language with which to tie together various areas in interdisciplinary communication. As such it automatically strives towards a universal science, i.e. to join together the many splintered disciplines with a 'law of laws', applicable to them all and integrating all scientific knowledge. Systems science can promote a culture wherein science, philosophy and religion are no longer separated from each other.

To engage oneself in systems science is therefore a highly cross-scientific occupation. The student will come in contact with the many different academic disciplines: philosophy, sociology, physics, biology, etc. The consequent possibility of all-round education is something particularly needed in our over-specialized society.

Contributions concerning all-round education include thoughts put forward by a number of distinguished people. ***François Voltaire*** once said: 'Education is the only quality which remains after we have forgotten all we have learned'. ***Oscar Wilde*** said in one of his plays: 'Education is a good thing but it ought to be remembered that nothing which is worth knowing can be taught.' A Swedish proverb tells us that: 'Education is not something which can be learned; it is something you acquire.'

In the following pages some Western system-theoretical outlooks and theories will be presented together with central concepts (the Eastern world has its own tradition although science is an offspring of Western civilization as a whole). Some philosophical aspects will also receive attention. The broad spectrum of knowledge will be introduced according to the funnel method: much will be poured in, but the output will be a defined flow of systems knowledge.

The natural starting point should be in the golden age of Greece, the cradle of Western modern human science. Beginning in the Middle Ages will (besides keeping the number of pages down) suffice to provide the background necessary to understand the origin of systems thinking and the subsequent development.

The scholastic paradigm

First we must realize that beliefs and knowledge in any era are influenced by concomitant time-dependent paradigms. That the medieval world view could be described with the help of the **scholastic paradigm** satisfied contemporary needs. Although this paradigm may be characterized as prescientific, it was a complete philosophy which wove together morality and heavenly systems with physical and worldly systems, creating one entity. This amalgamation was based on the following propositions:

- Nature was alive and thus mortal, vulnerable and finite.
- The universe and the nature of time was possible to understand.
- Salvation of the soul was the most important challenge.
- Natural sciences were subordinate to theology.
- The goal of science was to show the correlation between the world and spiritual truth.
- Knowledge was of an encyclopaedic nature, classified and labelled.
- The structure of society was influenced by Heaven and reflected a divine order. The cruciform mediaevial city was not only functional, in addition it was a religous symbol.

Scientific development was thus acknowledged only when it supported religion. The existing method with which to explain the complexities of phenomena was insight or revelation; curiosity as such was a sin. Observation, recording, experimentation and drawing objective conclusions were not encouraged. Nature was viewed as an organism created by God; to destroy Nature was to commit a sin. The natural forces were beyond human control; any protection from them would come from God or from witchcraft. Natural phenomena not understood were given a supernatural explanation. Goal-seeking, *teleology*, was built into nature: stones fell to earth because they belonged to the earth and strove to join their origin.

For the second century AD astronomer ***Ptolemy*** the Universe was of a static nature. No difference was made between reality and dream, between fact and judgement. *Alchemy* was not distinguished from chemistry, nor *astrology* from astronomy. Reason was often regarded as something irrelevant or offensive to the mysterious existence. The connection with reality was unformulated, imprecise, implicit and indeterminate. In physics, for example, one spoke about the five (later a sixth) basic substances. They were:

- Earth
- Air
- Fire
- Water
- Quintessence, including ether
- (Magnetism)

Psychology as a formal science was unknown. Mental qualities, such as *satanic, demonic, human, angelic, divine,* were nevertheless recognized, as were the following manifestations.

Deadly sins:

- Pride
- Covetousness
- Lust
- Envy
- Gluttony
- Anger
- Sloth

Cardinal virtues:

- Justice
- Prudence
- Fortitude
- Temperance

Divine virtues:

- Faith
- Hope
- Love

(Note that the virtues balance the sins.)

The Greek physician ***Galenos*** (131-201) produced a classification of human beings. According to him, each individual belonged to one of four classes defined by what kind of 'body fluid' was predominant. A certain connection between body fluid and type of personality was considered to be highly significant.

Dominant fluid:	Type of personality:
- Blood	- Sanguine
- Yellow gall	- Choleric
- Black gall	- Melancholic
- Slime	- Phlegmatic

An upset in the balance between the bodily fluids was considered to be the cause of an illness.

Despite of prevailing mysticism, it would be a mistake to consider the mentality of the Middle Ages as primitive. Behind this disregard for the physical world and the world of men lay the image of human existence as a trial. Life was considered to be a journey to heaven. The seemingly austere existence was abundantly compensated for by a rich mental life and a far-reaching spiritual imagination.

The Renaissance paradigm

With the coming of the 16th century the prescientific stage is succeeded by one in which science is acknowledged as capable of describing phenomena, as a route to knowledge. Science itself becomes a source for the development of new technologies. A growing respect for facts tested in valid experiments and a proficiency in the communication of knowledge and opinions emerges. Teleological explanations of observed regularities in human environment (the idea that physical systems are guided by or drawn towards a final goal), earlier seen as a *norm* for various phenomena, are gradually abandoned. In place of those, *laws of Nature* come to be formulated on a mechanical basis. By this means only factors directly influencing the course of events are considered.

A new possibility to cope with human existence is introduced with the emergence of increased knowledge in astronomy. With the discoveries of ***Nicolaus Copernicus*** (1473-1543) the geocentric world view is slowly abandoned in favour of a new heliocentric theory for the movements of celestial bodies. Influenced by earlier aesthetic preferences he continues to consider all planetary movements to be perfectly circular. Thoughts about an infinite Universe and world multiplicity vindicated by the philosopher ***Giordano Bruno*** (1548-1600) are considered to be so provocative by the church that he is sentenced to death and burned at the stake. ***Tycho Brahe*** (1546-1601) develops a newly elaborated technique for observation of planetary movements thereby improving the theory. His achievement is implemented by ***Johannes Kepler*** (1571-1630) to prove the elliptic nature of planet orbiting (The three laws of Kepler). Through the invention of the telescope by ***Galileo Galilei*** (1564-1642) it is possible to have a more realistic perspective on the planet Earth. The Earth can no longer be seen as the centre of all phenomena when it is one among several planets moving around the sun. The discovery of huge numbers of stars proves that the universe is both larger and more diverse than decreed by the Church and theologians. Teleological explanation of motion is discarded and motion is now seen as a force acting on bodies rather than these body's striving to join an origin. In the thoughts of Galilei we see the beginning of the mechanistic world view and the separation between religion and science. 'The world of nature is the field of science.'

Thanks to his experimental and mathematical approach, Galilei is considered to be the first modern scientist. As a researcher he differentiated between *quantitative* and *qualitative* properties. The latter, like colour, taste, and smell were descriptions for things existing only in our consciousness and therefore unfit for use within science (which had to be pursued by universal data originating from the objects).

Another researcher, ***René Descartes*** (1596-1650), contributes his integrated philosophy from chaos to cosmos. He extends the separation between religion and science to one between body and mind, *dualism*. Descartes differs between the body which belongs to the *objective* world of physical reality and that which belongs to the *subjective* world of the mind with its thoughts and feelings.

From here on, the Western religious tradition holding human beings as something unique in this world and perhaps in the universe, begins its implacable retreat. Human consciousness no longer mirrors a divine origin, only itself.

Most of the natural phenomena surrounding man seems however still to be inexplicable, i.e. without apparent causation. The explanations offered were of a purely superstitious nature. In spite of this, it is generally believed, as a principle if not in practice, that a complete understanding of the world is possible. When the Renaissance scientist looks about he sees his own world as a relatively small island of certainty surrounded by a sea of accepted mystery.

The birth of modern science must be seen in relation to the power of the church. The influence of the papal theocracy and the religious world view influenced the course of development. It was very little difference between priests and learned men. The trials of Giordano Bruno and Galileo Galilei showed that science was in danger if it interfered with social questions, that is, the domain and the authority of the Pope. Science has to declare itself independent and neutral, and concepts such as impartiality and objectivity soon became its hallmark, influencing modern civilization much more strongly than religion. The religious imperative of man's supremacy over himself is successively superseded by the scientific imperative of the human right to supremacy over nature.

In our own time, at the end of the 20th century, this classic scientific mentality has lost its significance. The concept of objectivity is however still relevant – if we acknowledge its limitations.

The mechanistic world and determinism

In the beginning of the 18th century, the view that we today call the 'scientific world view' is firmly established in European society, albeit dressed in clothes of its own time. Tradition and speculation are replaced by *rationalism* and *empiricism* with the assumption that natural phenomena can and must be investigated and explained. The inexplicable is now only a matter of 'undiscovered science'. The conception is that reality is determined, exact, formulated, explicit and that it is possible to control the natural forces.

The image of the world changes to that of a machine and the ambition of science is to dominate and conquer Nature. Such an entirely material world could be treated as if it were dead, letting man be the possessor and master of his environment, including all plants and animals, and even permitting the expansion of slavery. This world is also separated from the moral world with which it had been one during the mediaeval era. The spiritual and physical order which were synthesized within the Natural Law (now seen as a mathematical/ physical entity) are still influencing the whole universe. All the mysteries of nature can now ultimately be explained in mechanistic terms.

The physical world forms a machine wherein every subfunction could be calculated and events in one part of the universe have consequences for all other parts. In this classic determinism, to every effect there is a cause and to every action there is a reaction. Cause and event initiate a chain of interrelated events. In this eternal continuum annihilation of matter/energy is impossible.

'All things by immortal power
Near or far
Hiddenly
To each other linked are
That thou canst not stir a flower
Without troubling of a star.' (***F. Thompson*** 1897)

Astronomy becames the symbolic area for a materialistic world philosophy: a mechanistic universe of dead bodies passively obeying the order of blind forces. Even the general outlook on man changes and is mainly mechanistic. For many, mechanism has come to be the logical opposite to surperstition.

Men and animals are now in principle nothing more than very elaborate mechanical beings. The human heart becomes a pump obeying pure thermodynamical principles within a hydraulic/mechanical system. This mechanistic era is often called the *Machine Age*, a term rooted both in the world view presented here and in the central role played by machines in the industrial revolution.

The most important name in mathematics/physics of this era is ***Isaac Newton*** (1643-1727). In his *Principia* of 1687 concerning gravitation, Newton presents a working mechanistic universe, independent of spiritual order. In Newtonian mechanics the term initial condition denotes the material status of the world at the beginning of time. Status changes are then specified in the physical laws. Known positions and velocities for planets in our solar systems at one specific moment are thus enough to determine their position and velocities for all future time. Newton's laws therefore automatically had determinism built into them.

Pierre Simon de Laplace (1749-1827), a follower of Newton, is famous for his concept, the 'Laplace demon'. This demon knows the position and speed of every particle in the universe at any moment. Using Newton's laws, it calculates the future of the whole universe.

The idea of the universe as a clockwork mechanism is thus established. On this is founded the doctrine of determinism, implying the orderly flow of cause and effect in a static universe, a universe of being without becoming. Carried to its final extreme, *superdeterminism* is embraced by many of the scientists of the time. According to this world view, not even the initial condition of the universe could have been other than it was; it is determined exactly so by a determinism which determined itself.

The hegemony of determinism

A uniform world view is emerging, expressed in mechanistic terms. It is possible to comprehend the universe, at least fundamentally. This clockwork universe, having been wound up by the Creator, works according to the internal structure and the causal laws of nature. The purpose and meaning, the very existence is put outside of the universe itself. The distinction of a clockwork is just that its meaning is external to the machine and only exists in the mind of its creator. As a clockmaker is to a clock, so is God to Nature.

Clockwork is also presented as a central characteristic of the general *principle of causality*: that every effect is preceded, not followed, by a cause. Just as one cogwheel drives and influences the other in a rational way, a measurable cause always produces a measurable effect in any rational system. Also, identical causes imposed upon identical rational systems, always produce identical effects. Thus one cause/effect relation explains all existence, where the first cause was God.

Under these circumstances, the problem of free-will comes to the fore: free will is claimed to be an illusion. Meaning and freedom of choice lose their purpose in a deterministic universe; they are not necessary to explain natural phenomena and human behaviour. The cause explains the effects completely.

On the basis of this mental world view, *reductionism* becomes the predominant doctrine. Reductionism argues that from scientific theories which explain phenomena on one level, explanations for a higher level can be deduced. Reality and our experience can be reduced to a number of indivisible basic elements. Also qualitative properties are possible to reduce to quantitative ones. Colour can be reduced to a question of wavelength, hatred and love to a question of the composition of internal secretion, etc. Thus reductionism is inherent to all main fields of science, as is illustrated below.

- in physics : the atom with two qualities, mass and energy
- in biology : the cell, the living building block
- in psychology : the archetype instincts
- in linguistics : the basic elements of sound, the phonemes

Reductionism in turn provides a foundation for the analytical method with its three stages.

- Dissect conceptually/physically.
- Learn the properties/behaviour of the separate parts.
- From the properties of the parts, deduce the properties/behaviour of the whole.

Observations and experiments are the cornerstones of reductionist analytical methodology. Another prerequisite of this method is freedom from environment, that is, environment is considered to be irrelevant. The *scientific laboratory* concept standardizes, and thereby excludes, the environment. In this milieu the effect of different variables – those being observed by the scientist – can be studied in proper order without influence from the environment. Here various hypotheses about nature are tested in order to arrive at approximate answers. Here the ultimate scientific activity is exercised; to *describe*, *control*, *predict*, and *explain* the various phenomena. In this activity the scientist is presupposed to be outside of the experiment. The observer is not involved, at least ideally. The lodestar of the scientist becomes *non-intervention*, *neutrality* and *objectivity*.

The basic metaphysical presumption behind the concept of the laboratory is that nature is neither *unpredictable* nor *secretive* and that it is *computationally reversible*. Predictability implies that the same laws of nature are valid in all parts of the universe. It also implies that the physical states are influenced by laws, but not vice versa. By non-secrecy is meant that all aspects of nature are in principle possible to reveal, albeit that this will sometimes take an extremely long time. The same experiment performed by different observers in different parts of the universe and at different times should always give the same results (*intersubjectivity* and *repetitionality*). Dissimilar results are attributed to human deficiency or deception and will be corrected through better precision of the experimental design. Computational reversibility implies that, given all necessary knowledge, it is possible to calculate what happened in a previous instance, that is, that nothing changes with time.

Through analytical science *The Scientific Method* is established with its own approach following the order presented on the next page.

- reduction of complexity through analysis
- development of hypotheses
- design and replication of experiments
- deduction of results and rejection of hypotheses

This methodology, albeit still with its basic metaphysical assumptions, now becomes the cornerstone of empirical science. It entails a rational, empirical process of inquiry from observation to the formulation of hypotheses and further via experiments to theory. Its strength is its exclusive consideration of relevant fact for what is in focus. An examination of weight thus entirely excludes the colour of the investigated object.

Thus the aim of the method is to bring about a fixed path reasoning appropriate for all kinds of problems. The person who uses it can be assured that he has not been outwitted by nature to believe something that he actually does not know. Note, however, that a scientific accomplishment obtains a value only when it is unrestrictedly and officially communicated to others. Thanks to this implied fifth and imperative step of the methodology, comments and corrections of the result can be fed back to the researcher. This will initiate new ideas and experiments which in turn ensure that the accumulation of knowledge never halts.

Classic empirical science is able to produce not only theories explaining existing phenomena but also theories revealing phenomena not yet discovered. It can even use methods which create unexplained theories in search of phenomena. Abstract elegant theories waiting for a practical application are part of the history of science.

This scientific method lays the ground for a certain kind of mentality and a marked homogenous world view based on the concepts of *empiricism*, *determinism* and *monism*. While empiricism is the doctrine that the universe is best understood through the evidence confronting our senses, determinism is the belief in the orderly flow of cause and effect. Monism implies the inherent inseparability of body and mind, a prerequisite in all European thinking. The above concepts taken together are often referred to as the *Scientific Paradigm*. In the study of electricity, magnetism, light and heat the Scientific Paradigm has great success. Within a short time general mathematical laws are formulated which show the interrelationship between the different areas.

Human optimism grows rapidly: science is expected to give the ultimate answers to questions within all areas. *Scientific positivism* with its demand for 'hard facts' acquired through experience is brought into fashion by ***Auguste Comte*** (1798-1857). Concepts like cause, meaning and goal are weeded out of the natural sciences. Only a reality possible to observe with our senses and possible to treat logically can be accepted as a basis for reliable knowledge. The role of the scientist should be that of the objective observer, explaining and predicting. The collection of absolute facts and the quantification of these are the main occupation of the scientist.

This positivist mentality can be summed up using the following concepts.

- **Philosophical monism** Body and mind are inseparable.
- **Objective reality** A reality possible to experience with our senses.
- **Nominalism** All knowledge is related to concrete objects. Abstractions lack a real existence.
- **Empiricism** All knowledge is founded on experience.
- **Anti-normativism** Normative statements do not belong to science as they are neither true nor false.
- **Methodological monism** Only one method of scientific research exists, that given us by the scientific paradigm.
- **Causal explanations** Goals, intentions and purpose are irrelevant.

At the end of this era of classical determinism, the mechanistic interpretation of thermodynamics leads to new insights. The two main laws of thermodynamics are formulated through works of ***Rudolph Clausius*** (1822-1888), ***William Kelvin*** (1824-1907), ***Ludwig Boltzmann*** (1844-1906) and ***James Maxwell*** (1831-1879), the originator of Maxwell's demon. This is a metaphysical thermodynamic being who apparently neglects the second law by decreasing the entropy into an isolated system. The concept of *entropy* is introduced as an abstract mathematical quantity, the physical reality of which retains a shroud of mystery.

The **first law of thermodynamics** says: The total energy in the universe is constant and can thus be neither annihilated nor created. Energy can only be transformed into other forms. (The principle of conservation of energy with regard to quantity.) In a sense, this law had already been formulated 500 years B.C. by the Greek mathematician Pythagoras who said 'everything changes, nothing is lost'.

The **second law of thermodynamics** states that all energy in the universe degrades irreversibly. Thus, differences between energy forms must decrease over time. (The principle of degradation of energy with regard to quality.) Translated to the area of systems the law tells us that that the entropy of an isolated system always increases. Another consequence is that when two systems are joined together, the entropy of the united system is greater than the sum of the entropies of the individual systems.

Potential energy is organized energy, heat is disorganized energy and entropy therefore results in dissolution and disorder. The sum of all the quantities of heat lost in the course of all the activities that have taken place in the universe equals the total accumulation of entropy. A popular analogy of entropy is that it is not possible to warm oneself on something which is colder than oneself. The process of human ageing and death can serve as a pedagogic example of entropy. Another common experience is that disorder will tend to increase if things are left to themselves (the bachelor's housekeeping!).

Inasmuch as there is a mathematical relation between probability and disorder (disorder is a more probable state than order), it is possible to speak of an evolution toward entropy. Below some well-known expressions illustrates this process.

Probability	Improbability
- Disorder	- Order
- Disorganized energy (heat)	- Organized energy
- Heat (low–grade energy)	- Electricity (high-quality energy)
- Entropy	- Syntropy

The above process derives from the second law of thermodynamics and has had a tremendous impact on our view of the universe. One consequence is to experience the world as *indeterministic* or as chaotic. The ultimate reality is the blind movements of atoms whereby life is created as a product of chance, and evolution is the result of random mutations. Another is that the Newtonian world machine has a persistent tendency to run down; the Creator must wind up the celestial clockwork from time to time. Any event that is not prohibited by the laws of physics should therefore happen over and over again.

Today we can see how these perspectives, together with the image of the inevitable death of the universe, have significantly influenced philosophy, art, ethics, and our total world view. This image has inflicted upon the Western culture some form of paralysis. For the generations of researchers nurtured *via* this period's mentality, a physical eternity without purpose seemed to be the basis for all reality. For these people the Universe could be described as 'big and old – dark and cold', quoting the contemporary geologist George Barrow. The French physician ***Léon Brillouin*** (1889-1969) sums everything up in his question 'How is it possible to understand life when the entire world is organized according to the second law of thermodynamics which points to decay and annihilation?'

The era of determinism coincides with both the era of machines in the industrial revolution and the conservative Victorian culture. Human skills are increasingly taken over by machines; the remaining manual tasks are broken down into a series of simple and monotonous manipulations. This dehumanization of productive effort and the subsequent alienation of the worker gives rise to mental phenomena such as Marxism-Leninism.

The deterministic era can also be named the age of *scientism*, with reference to the belief that only concepts which can be expressed in the language of the exact natural sciences and proven by quantification have a reality. It assumes the existence of an objective reality, including dichotomies contrasting man and nature, mind and matter, facts and values. Its primary concern is to discover truth, regarding questions of values and needs as outside the realm of scientific inquiry. Scientism is also synonymous with the 'objective' mode of presentation of results, used by many researchers of this era. That courage, despair and joy are important prerequisites for a successful result is neglected - for entirely subjective reasons.

In the deterministic interpretation of the second law of thermodynamics it is possible to find the roots of the pessimism prevailing at the turn of the century. The sun is exhausting its life-giving resources, the earth is approaching a new glacial period and the society is declining. Inferior army discipline, general decadence, falling birth rate, spread of tuberculosis are all visible effects of increased entropy. Emotionally, cosmic and physical values are never separated from a human system of evaluation. The resulting gloominess, the *fin de siècle* mode, is excellently presented in European literature of this period.

While a 300-year-old attitude towards reality draws to its end, the dissolution of determinism gives room for new impulses and new perspectives.

The age of relativity and quantum mechanics

The first fatal blow to determinism with its static view of the universe comes from ***Albert Einstein*** (1879-1955) in 1905, in his *special* theory of relativity. An event is defined with four numbers: three for the position in space and one for time. These constituents do not exist individually; it is not possible to imagine time without space, or vice versa. When a star is observed at a distance of one hundred light-years, the star is not only this far away in space but it is also observed as it was one hundred years ago. The four-dimensional space with its space/time continuum is introduced.

The contradiction between this theory and Newton's theory of gravitation poses a problem. Einstein solves it in 1915 by introducing the *general* relativity theory, where gravitation is a consequence of the nonflat curving space/time caused by the content of mass and energy. The mass of the sun curves the space/time into a circular orbit in the three-dimensional world even if it is a straight line in the four-dimensional world. Einstein's synthesis of the fundamental quantities of time, space, mass, and energy is confirmed first in the 1930s through astronomical observations.

For the general public living in the first part of the twentieth century, the scientific world view represented by Einstein's theories was sometimes more than incomprehensible. A contemporary view of the general relativity theory may be found in the following limerick:

There was a young lady girl named Bright,
Whose speed was far faster than light,
She travelled one day,
In a relative way,
And returned on the previous night. (***R. Buller***)

Another death blow to determinism was *quantum theory*. It had been enunciated already 1901 by the German physicist ***Max Planck*** (1858-1947). With this theory the classic concept of mechanics starts its reformulation. In 1927 it is ***Werner Heisenberg*** (1901-76) who frames *the uncertainty principle*: it is fundamentally impossible to simultaneously define position and velocity for a particle. Heisenberg's principle must be considered a special case of the *complementarity principle*, also articulated in 1927 by ***Niels Bohr*** (1885-1962). This states that an experiment on one aspect of a system (of atomic dimensions) destroys the possibility of learning about a complementarity aspect of the same system. Together these principles have shocking consequences for the comprehension of entropy and determinism.

The new mechanics, *quantum mechanics*, thus includes indeterminism as a fundamental principle when it focuses on the atom and its particles. In this small-scale system, the predominant and special circumstances are explained with the help of quantum theory. This theory concerns *probabilities* rather than certainties. Although concerned solely with extremely small particles, the theory reveals some extraordinary circumstances in physics. One is 'A spooky action at a distance', as Einstein called the *spectral effect*. A pair of correlated particles which have at one time been connected continue to influence each other instantly even after they have moved to separate parts of the universe.

Another circumstance is that electrons will not jump from one energy level to another while they are being watched, the *zeno effect*. This illustrates a basic phenomenon within quantum physics; the interpreter and the interpreted do not exist independently. Thus, interpretation is existence and existence is interpretation.

While quantum theory is not the final answer in physics, it has definitely opened a completely new way of thinking; its impact on the perception of reality and our world view should not be underestimated. Today, most scientists agree on a world view in which global determinism points in a main direction; they agree that local development determines its own non-predictive path, open to causal influences coming from both lower and higher levels.

The predominant cosmological view, called the *standard model,* tells us that the universe is expanding and has as its starting point in time the *big bang* of 15 billion years ago (the greatest effect of all with no cause!). The universe has then developed from an incredibly tightly-packed system, a *singularity*, where the natural laws as we know them did not exist. This condition cannot be described with the help of *either* a theory of relativity *or* the quantum theory. These can at most be seen as components of a not yet existing final theory.

We are now nearing the end of the 20th century. What was begun by Galileo, continued by Newton and finished by Einstein has over time inspired even poets:

'Nature and nature's laws lay hidden in night
Let Newton be God said and all was light'. (***Alexander Pope***)

'But then the devil cried that Einstein had to do
his work and reestablish status quo'. (***John Collings***)

These small poems implicitly question whether we can understand the world surrounding us and theories about it. Theories such as the quantum theory cannot actually be proved. If they are mathematically consistent and observations coincide with predictions, the probability is however high that they describe reality reasonably well. Today, the rules of quantum theory have been around for a long time and must be considered neither wrong or incomplete. But modern science based on quantum theory has come to realize that it is impossible to conclusively describe and understand the natural world. To this may be added that even if modern science was able to explain *how* the Universe is structured, it cannot say *why*.

Scientists today tend to agree that when we formulate the theories of the atomic world, we are doing it *vis-à-vis* not the reality but rather our knowledge regarding reality. Physics, for example, does not claim anything about something actually existing, but rather informs our knowledge concerning that which we claim exists. The models of physics no longer explain, they only describe. Therefore, in a way, fundamental physics today is a matter a of philosophy, while cosmology has been a kind of scientific poetry.

A consequence of this attitude is that it is possible to claim that the world only exists in the spectator's mind, that an observation is dependent upon the observer. This philosophical shattering of reality echoes the claim of ***Immanuel Kant*** (1724-1804) that the concepts of space and time were necessary forms of human experience, rather than characteristics of the universe. Kant considered that it is not only the consciousness which adapts to things, but things also adapt to the consciousness. This kind of physical idealism is well expressed in another limerick:

There once was a man who said 'God
Must think it exceedingly odd
If he finds that this tree
Continues to be
When there's nobody else in the quad.' (***Ronald Knox***)

The view that only one truth about reality exists and that the various scientific disciplines describe different parts of it is no longer tenable. What exists is only subjective and often contradictory conceptions of reality. The decline of the illusions of the pre-Einstein natural science shows that not even scientific results are absolute. In due time they are replaced by theories and models having an extended descriptive and predictive value. Present-day knowledge is only the best description of reality we have at the current moment in time.

Werner Heisenberg is reported to have said: 'A quantum world does not exist. The only thing which exists is our abstract description of the physical reality.' ***Niels Bohr*** (1885-1962) also said: 'Physics is only about what we can say concerning nature.' There is no point in asking how matter could be constituted behind our observations of it, as these are the only evidence we can ever have. According to this view, quantum theory should not be understood as a description of the world, but rather as an instrument enabling the human mind to make predictions and calculations.

Albert Einstein took a slightly different view when he said: 'The firm laws of logic are always valid, and nature's laws are indifferent to our attitude.' Thus Einstein claimed that the world exists independent of human beings and that it is only in part comprehensible. Einstein's pursuit of the old rationalist tradition in Western science that reality has an objective existence independent of the observer is thus today questioned by many researchers.

The multiple perspectives, issuing from the modern, relativistic science, have actualized the dualism between substance and awareness, the classic body/mind problem. Our conventional definition of self-consciousness includes totality and consistency in time and space. Such self-consciousness can be achieved only by a creative human intelligence. Quantum physics claims that consciousness *per se* may be seen as the particle's *mental* existence in wave form defined by cooperation, interference and overlapping. It exists everywhere and has knowledge of what happens in other places. The particle's *physical* existence is its permanence as matter with mass and position in space. On the basis of the above we can identify the following internal respective external opposites:

– consciousness	– body
– subject	– object
– individual	– environment
– culture	– nature

A number of proposals taken from the area of relativity theory and quantum physics and are presented below. Many of these are paradoxical.

- There is an infinite number of worlds and we exist parallel in them.

- Time goes both backward and forward at the same time.

- Matter and consciousness are the same thing.

- A particle exists in several places at the same time when manifested as a wave form. Although it can only be observed in one place at a time, it does exist in several spaces simultaneously.

- Quantum physics concerns probabilities. Quantum wave functions express all probabilities simultaneously. When someone observes, the probability becomes a reality with fixed properties. Other possibilities vanish.

- In the world of quantum physics everything is interconnected. Everything exists everywhere simultaneously, but can only be observed as an object in one universe at a time.

- The quantum wave is a connection through all time both in future and past time.

- What we remember of past times has been determined by something in the future. Both past and future have existed before, the future in a parallel universe.

- When we choose to observe something, we create and influence it.

- Observations create consciousness and consciousness creates the material universe.

- The existence of matter and consciousness is the same thing.

- The existential basis for all matter is meaning.

- Radio-transmitted music confined in the form given by the radio wave exists as a potentiality; it is heard only when the receiver is turned on.

- Quantum fields of potential information are everywhere omnipresent. Their meaning is existence. To change the meaning changes the existence.

- The mental and the physical world are two sides of the same coin. They are separated by consciousness only, not by reality.

- Meaning and purpose are inherent parts of reality, not an abstract quality in the human mind.

Quantum theory has seriously undermined science's faith in an external, material reality and has implied a repudiation of scientism and a rigorous positivistic empirical science. The potential of dead matter to produce living matter and consciousness signifies a recognition of purpose, of creation and self-organization. The function of living matter is apparently to expand the organization of the universe. Here locally decreased entropy as a result of biological order in existing life is invalidating the effects of the second law of thermodynamics, although at the expense of increased entropy in the whole system.

Strict determinism is no longer valid; the development of our universe is decided both by chance and necessity, by random and deterministic causes working together in entropy, evolution, continuity and change. These universal principles – sometimes called **syntropic** (***Fuller*** 1992) – counteracting decay and destruction (the second law of thermodynamics), will create a new and more flexible world view.

Another challenge to positivistic science is the idea that the universe itself is a living phenomenon, irrespective of its organic inhabitants. The creation of new stars, their growth, reproduction and death, together with their metabolism, justify the use of the term 'living' in the eyes of many scientists.

The concept of value is not inherent to science; classical science never asks why or what for. Nor is speculation as to the cause, meaning and ultimate goal an attribute of its method. The second law of thermodynamics, expressing the diffusion and deterioration of matter and existence, has long represented the classical science mentality and influenced the construction of methods and instruments. Today, with a growing awareness of the universe undergoing a creative and problem-solving evolution, values can add new and fruitful dimensions to classical science.

On the basis of the above outline of this scientific development and the consequences thereof for the present-day world view, some observations can be emphasized. A gratifying, and astonishing, fact is that the classic natural laws formulated by Newton, for example, are still going strong. While piece after piece has been added to the theoretical building by new generations of scientists, it has not yet been necessary to demolish its main structure and start from scratch again.

The Newtonian gravitational theory has influenced Einstein's theory of relativity. Through Einstein's theories Newton's equations have become more complex; Newton's original theory is nonetheless still valid and gives us in most cases very good approximations. Newton's mechanics has now become a 'special case' within Einstein's theory of relativity. The counter-intuitive sub-atomic paradoxes of quantum physics do not interfere with the common sense of everyday life, although they are very extensive in for example microelectronics.

Regarding the relation between relativity theory and quantum theory, the latter suggests that space and time are approximate concepts, which may have to be abandoned when the infinitely small is contemplated. Thus large-scale mechanics and quantum mechanics have been forced to co-exist, because neither is any good at explaining the other.

Another observation is that the classical division of the disciplines was to a great extent conditioned by – but also reflected – the order of nature, mind and society of its time (that is, the well-organized Victorian society). This is expressed by Comte's hierarchy of development in science with its three stages.

- The theological stage (corresponding to the scholasticism)
- The metaphysical stage (corresponding to the the Renaissance)
- The positive stage (corresponding to the mechanistic era)

At the same time it is possible to see a reductionist hierarchy in the various scientific disciplines when arranged in order according to 'size'.

- Astronomy
- Sociology
- Psychology
- Biology
- Chemistry
- Physics

Further, the various disciplines in science have undergone a similar development and show a parallelism in their development of methods. Every field of human knowledge thus passes through distinct stages.

- Intuition
- Fact-finding
- Analysis
- Synthesis

Synthesis is a prerequisite for the **systems thinking** of our own time, just as analysis was for the mechanistic era. A system inasmuch as it is a whole, will lose its synergetic properties if it is decomposed; it cannot be understood through analysis. Understanding must therefore progress from the whole to its parts – a **synthesis**. Synthesis takes the steps of analytical science (see p. 10) in reverse order.

- Identify the system of which the unit in focus is a part.
- Explain the properties or behaviour of the system.
- Finally, explain the properties or behaviour of the unit in focus as a part or function of the system.

Synthesis does not create detailed knowledge of a system's structure. Instead, it creates knowledge of its function (in contrast to analysis). Therefore, synthesis must be considered as **explaining** while the scientific method must be considered as **describing**.

Systems thinking **expands** the focus of the observer, whereas analytical thinking **reduces** it. In other words, analysis looks into things, synthesis looks out of them. This attitude of systems thinking is often called **expansionism**, an alternative to classic reductionism. Whereas analytical thinking concentrates on **static** and **structural** properties, systems thinking concentrates on the function and behaviour of whole systems. Analysis gives description and knowledge; systems thinking gives explanation and understanding. With its emphasis on variation and multiplicity, rather than statistically ensured regularities, systems thinking belongs to the holistic tradition of ideas.

Systems thinking is a response to the failure of mechanistic thinking in the attempt to explain social and biological phenomena. As an attempt to solve the crisis of classical science it has formulated new approaches in scientific investigation. Primarily, it dates back to the 1920s when emergent properties in living organisms were generally recognized. Born in biology, it is easy to understand that the systems movement has acquired the major part of its terminology from that area when considering terms like autonomy, survival, etc.

It is now possible to note how the specific tools in the various areas have emphasized the different stages. The tools for the analysis were *par excellence* the microscope and the telescope, tools which must be considered to be reductionist promotive. The tools of the emerging systems age are designed to enhance synthesis and have often taken over the function of the classical laboratory. The computer has become a viable substrate for experimentation. Research in many fields such as nuclear, aerodynamics, biology, chemistry, etc., is now being simulated instead of actually performed. The particle accelerator combines analytic and synthetic properties in a kind of super microscope capable of the resolution of objects less than the diameter of the atomic nucleus. Satellites orbiting the earth give outstanding possibilities for the understanding of global phenomena and for the first time in history humanity has now the opportunity to look upon itself from the outside. Tools with the above-mentioned properties are often called **macroscopes**.

The systems age

In the 1950s, with the introduction of computers, hydrogen bombs and space exploration, large-scale problems began to penetrate Western society. The traffic-system breakdowns, environmental disasters and the nuclear threat were immediately high on the agenda. Society was faced with *messes*, interacting problems varying from technical and organizational to social and political.

It was suddenly realized that many solutions were inadequate when applied to problems which no longer existed in their original form. Change itself, with its accelerating rate, was a major concern. Two hundred years of success for classical science and technology had created a form of development the long-term effects of which apparently were programmed to be devastating for humanity. ***Gerald Weinberg*** states in one of his books that 'science and engineering have been unable to keep pace with the second order effects produced by their first order victories'.

The following examples address some of the problems:

- environmental destruction and climatological changes
- deforestation and desertification
- garbage accumulation, nuclear radiation, water, soil, and air pollution
- acidification, decreasing subsoil water and shrinking ozone layer
- decreasing biodiversity and extinction of species
- population explosion and criminalization
- urbanization, unemployment, and proletarianization
- energy wastage and resource depletion
- motorization and noise pollution
- data pollution, lack of information and knowledge
- commercialization and cultural impoverishment
- mental corruption, drug abuse and AIDS
- environmental ugliness with growing amounts of concrete and asphalt
- bureaucratization, passivisation and dulling of the human intellect

Classical science, with its overspecialization and compartmentalization, had already proved its inability to handle problems of such tremendously increased complexity. Its attempt to reduce complexities to their constituents and build an understanding of the wholeness through knowledge of its parts is no longer valid. Not understanding that the wholes are more than the sum of their parts, scientists had assembled knowledge into islands, extending into an archipelago of disconnected data.

Not long ago physics was regarded an archetype for all genuine science. A reductionary chain was envisaged where psychology was deducted to neurophysiology, neurophysiology to biochemistry and biochemistry in turn to quantum mechanics. Today, modern biology has shown that this kind of reductionism is out of the question. Physics, chemistry and biology have united with each other into molecular biology – a new overarching description system separated from the area of both physics and chemistry.

Many scientists have now realized that the way they had embraced the world was not far-reaching enough to understand and explain what they observed and encountered. As ***Gary Zuchov*** (1979) says in his book *The Dancing Wu-Li Masters*: 'Their noses had been too deeply buried in the bark of a special tree, to be able to discuss forests in a meaningful way.' It was thus accepted that systems are wholes which cannot be understood through analysis inasmuch as their primary properties derive from the interactions of their parts. Furthermore, interaction between systemic variables are so integrated that cause and effects cannot be separated – a single variable could thus be both cause and effect.

Thus awareness grew that everything in the universe – including themselves

– which seems to exist independently was in fact part of an all-embracing organic pattern. No single part of this pattern was ever really separated from another. It was possible to catch a glimpse of a universality of systemic order and behaviour which characterized both living and nonliving systems. That humans now had got access to some of the main design principles of the universe implied that they too were included in the drawings for some very significant ultimate purpose.

Earlier, the alternative to systemic intervention was to suffer the consequences, to endure whatever happened; scientists had too often waited for systems failures to see what these could reveal about the mechanism. Today function, not anatomy, is the main point. The important task is to solve problems in real life. To describe and understand were not values in themselves; their purpose was to enhance the capability for large-scale system prediction and control.

The technicians strove to have things work well, the social scientist to have things behave well. Science was to become more **ethical,** less **philosophical.** To do things, was considered to be more important than to think about them. In these circumstances emerged the new **interdisciplinary** and **holistic** approach. Here holism was an attempt to bring together fragmentary research findings in a comprehensive view on man, nature, and society. In practice it was a search of an outlook to *see better*, a network to *understand better* and a platform to *act better*.

Without hesitation this had it roots in the war-time efforts and the special mentality of **operational research.** This 'emergency-discipline' handled military strategic decisions, resource allocations, optimal scheduling and risk analysis, etc., in a truly pragmatic way, all in order to win the war. Its main guidelines were the following:

- It is not necessary to understand everything, rather to have it under control. Ask what happens instead of why.

- Do not collect more information than is necessary for the job. Concentrate on the main consequences of the task, the small details may rest in peace.

- Solve the problems of today and be aware that prerequisites and solutions soon become obsolete.

Operational research gave rise to the first successful methodology where the problem complex not was disassembled into disciplinary parts and could be treated as one entity by different researchers.

In 1954 the International Society for General Systems Theory, ISGST, was founded. This society later become the International Society for Systems Science, ISSS. Two of the most prominent founders were ***Ludwig von Bertalanffy*** and ***Kenneth Boulding***. Although Bertalanffy had formulated his ideas already in the

1930s, he was not recognized until one of his now classic papers on systems theory appeared in the American journal *Science* in 1950. Then, the idea that systems had general characteristics independent of the scientific areas to which they belonged was both new and revolutionary. Boulding in turn published his well-known system hierarchy in 1956.

The founding team of interdisciplinary scientists, had a shared interest in a universal science. They wanted to link together the many splintered disciplines with a **law of laws** applicable to them all. The following aims were stated:

- to integrate similarities and relations within science;
- to promote communication across disciplinal boundaries;
- to establish a theoretical basis for general scientific education.

Integration should be promoted by the discovery of analogies and isomorphisms and the new science should be a tool with which to handle complex systems. **Analogies** are explanations done by relating something not yet understood to something understood. **Isomorphism** exists when common characteristics, structures, formulas and form of organization are in accordance in different systems. That is, when formally identical laws governing the functioning of materially different phenomena exist. A partial accordance is generally referred to as **homomorphism**. The use of isomorphism made possible the indirect study of systems in terms of other systems (simulation) and the use of content-independent methods within different scientific areas.

Step by step a theory was established: the **General Systems Theory** or **GST**. As a basic science it deals on an abstract level with general properties of systems, regardless of physical form or domain of application, supported by its own metaphysics in **Systems Philosophy**. General Systems Theory was founded on the assumption that all kinds of systems (concrete, conceptual, abstract, natural or man-made) had characteristics in common regardless of their internal nature. These systems could serve to describe nature and our existence.

Expressed in more precise terms, the goal of General Systems Theory can be specified as follows:

- To formulate generalized systems theories including theories of systems dynamics, goal-oriented behaviour, historical development, hierarchic structure, and control processes

- To work out a methodological way of describing the functioning and behaviour of systems objects

- To elaborate generalized models of systems

As an applied science, GST became **Systems Science**, a *metadiscipline* with a content capable of being transferred from discipline to discipline. Its equivalent to the classical laboratory become the computer. Instead of designing experiments with real materials, the computer itself became a viable substrate for experimentation. The use of computers as instruments for calculations, simulations and the creation of a non-existing reality thus brought about a new phenomenon that is neither actual nor imaginary, a phenemenon or mode that was called *virtual*. The computer is a virtual reflection of a non-existing mechanical adding machine. To be precise, it is an abstract entity or process that has got physical expression. In itself, it is a simulation, a simulation which is not necessarily a simulation of anything actual. 'Virtual' is thus a mode of simulated existence, resulting from computation.

The aim of systems science was, however, not to replace, but to complement traditional science. The systems perspective naturally acquired greater significance with the growing complexityof all systems, including and embracing man. Gerald Weinberg (1975) says about systems science that it has '...taken up the task of helping scientists to unravel complexity, technologists to master it, and others to learn to live with it.'

The aim of systems science was however not to replace but to complement the traditional science. The systems perspective quite naturally acquired greater significance with the growing complexity of all the systems including and embracing man. **General systems thinking** based on systems theory became its hallmark with the aim of fostering generalists qualified to manage today's problem better than the specialists. Specific individual methods were developed, many of which included modelling, simulation and gaming.

One of these methods, the **Systems Approach**, in reality an application of Systems Theory, operates in an integrated framework of modern organizational knowledge and management science. The Systems Approach is based on the fundamental principle that all aspects of a human problem should be treated together in a rational manner. It is an attempt to combine *theory*, *empiricism* and *pragmatics* and looks at a system from the top down rather than from the bottom up.

Another method, **Systems Analysis**, adopting a strictly systemic outlook on complex organizations, entered the scientific scene to ensure that no important factors in the structure were excluded. Problems of identifying, reconstructing, optimizing, and controlling an organization, while taking into account multiple objectives, constraints and resources are worked up. Possible courses of action, together with their risks, costs and benefits are presented. Systems analysis can thus be considered an interdisciplinary framework of the common problem-view.

An extension of this method, called **Anasynthesis**, was introduced with the implicit assumption that the more views one can apply to it, the better a problem can be understood. When using this method, *modelling, simulation, gaming, analysis* and *synthesis* are all applied to the development of a system. The method is used iteratively at both the macro and micro levels of large-scale systems. Normally, the outcome is more organized, structured and responsive to real-life requirements than are outcomes of other methods.

A number of proposals taken from the area of relativity theory and quantum physics are presented below. Many of these are paradoxical but one has to bear in mind that they relate to microcosmos and not our conventional environment.

- There is an infinite number of worlds and we exist parallel in them.
- Time goes both backward and forward at the same time.
- Matter and consciousness are the same thing.
- A particle exists in several places at the same time when manifested as a wave form. Although it can only be observed in one place at a time, it does exist in several spaces simultaneously.
- Quantum physics concerns probabilities. Quantum wave functions express all probabilities simultaneously. When someone observes, the probability becomes a reality with fixed properties. Other possibilities vanish.
- In the world of quantum physics everything is interconnected. Everything exists everywhere simultaneously, but can only be observed as an object in one universe at a time.
- The quantum wave is a connection through all time both in future and past time.
- What we remember of past times has been determined by something in the future. Both past and future have existed before, the future in a parallel universe.
- When we choose to observe something, we create and influence it.
- Observations create consciousness and consciousness creates the material universe.
- The existence of matter and consciousness is the same thing.
- The existential basis for all matter is meaning.
- Radio-transmitted music confined in the form given by the radio wave exists as a potentiality; it is heard only when the receiver is turned on.
- Quantum fields of potential information are everywhere omnipresent. Their meaning is existence. To change the meaning changes the existence.
- The mental and the physical world are two sides of the same coin. They are separated by consciousness only, not by reality.

- Meaning and purpose are inherent parts of reality, not an abstract quality in the human mind.

Quantum theory has seriously undermined science's faith in an external, material reality and has implied a repudiation of scientism and a rigorous positivistic empirical science. The potential of dead matter to produce living matter and consciousness signifies a recognition of purpose, of creation and self-organization. Living systems inevitably emerge as soon as the prerequisites are by hand. According to this view, life is a consequence of the structure of the Universe rather than a random event. The function of living matter is apparently to expand the organization of the universe. Here, locally decreased entropy as a result of biological order in existing life is invalidating the effects of the second law of thermodynamics, although at the expense of increased entropy in the whole system. It is the running down of the universe that made the sun and the earth possible. It is the running down of the sun that made life and us possible. And the price of indentity in life is mortality — conteracted by the fact that family and species live longer than one of us.

Strict determinism is no longer valid; the development of our universe is decided both by chance and necessity, by random and deterministic causes working together in entropy, evolution, continuity and change. These universal principles — sometimes called *syntropic* (***Fuller*** 1992) — counteracting decay and destruction (the second law of thermodynamics), will create a new and more flexible world view.

Another challenge to positivistic science is the idea that the universe itself is a living phenomenon, irrespective of its organic inhabitants. The creation of new stars, their growth, reproduction and death, together with their metabolism, justify the use of the term 'living' in the eyes of many scientists.

The concept of value is not inherent to science; classical science never asks why or what for. Nor is speculation as to the cause, meaning and ultimate goal an attribute of its method. The second law of thermodynamics, expressing the diffusion and deterioration of matter and existence, has long represented the classical science mentality and influenced the construction of methods and instruments.

Today, with a growing awareness of the universe undergoing a creative and problem-solving evolution, values can add new and fruitful dimensions to classical science.

On the basis of the above outline of this scientific development and the consequences thereof for the present-day world view, some observations can be emphasized. The first is that the disintegration of classic physics initiates the dissolution of art and morality. Proust's soundings in human memory, Picasso's insurrection against the perspective and Schonberg's musical revolution in tone, harmony, and rhythm is coherent with a new scientific world-view. There, the concepts of time and room have got a new and radical change. The discoveries of Planck and Einstein corresponded better with Freud's mapped dream-world than with the conventional perceived, empirical world. The reaction of the then existing man against modernism was an uneasiness caused by the ever increasing enstrangement of science and art from the area of immediate intelligibility. Today art and literature reflect the fragmentation of Western civilization.

A second and astonishing observation is that the classic natural laws formulated by Newton, for example, are still going strong. While piece after piece has been added to the theoretical building by new generations of scientists, it has not yet been necessary to demolish its main structure and start from scratch again.

The Newtonian gravitational theory has influenced Einstein's theory of relativity. Through Einstein's theories, Newton's equations have become more complex; Newton's original theory is nonetheless still valid and gives us in most cases very good approximations. Newton's mechanics has now become a 'special case' within Einstein's theory of relativity. The counter-intuitive subatomic paradoxes of quantum physics do not interfere with the common sense of everyday life, although they are very extensive in for example microelectronics. Regarding the relation between relativity theory and quantum theory, the latter suggests that space and time are approximate concepts, which may have to be abandoned when the infinitely small is contemplated. Thus large-scale mechanics and quantum mechanics have been forced to co-exist, because neither is any good at explaining the other.

Another observation is that the classical division of the disciplines was to a great extent conditioned by — but also reflected — the order of nature, mind and society of its time (that is, the well-organized Victorian society). This is expressed by Comte's hierarchy of development in science with its three stages.

- The theological stage (corresponding to the scholasticism) with magic and religion.
- The metaphysical stage (corresponding to the the Renaissance) where theology has been replaced by philosophy.
- The positive or the scientific stage (corresponding to the mechanistic era).

At the same time it is possible to see a reductionist hierarchy in the various scientific disciplines when arranged in order according to 'size'.

- Astronomy
- Sociology
- Psychology
- Biology
- Chemistry
- Physics

Further, the various disciplines in science have undergone a similar development and show a parallelism in their development of methods. Every field of human knowledge thus passes through distinct stages.

- Intuition
- Fact-finding
- Analysis
- Synthesis

Synthesis is a prerequisite for the **systems thinking** of our own time, just as analysis was for the mechanistic era. A system inasmuch as it is a whole, will lose its synergetic properties if it is decomposed; it cannot be understood through analysis. Understanding must therefore progress from the whole to its parts — a **synthesis**. Synthesis takes the steps of analytical science (see p. 15) in reverse order.

- Identify the system of which the unit in focus is a part.
- Explain the properties or behaviour of the system.
- Finally, explain the properties or behaviour of the unit in focus as a part or function of the system.

Synthesis does not create detailed knowledge of a system's structure. Instead, it creates knowledge of its function (in contrast to analysis). Therefore, synthesis must be considered as **explaining** while the scientific method must be considered as **describing**.

Systems thinking **expands** the focus of the observer, whereas analytical thinking **reduces** it. In other words, analysis looks into things, synthesis looks out of them. This attitude of systems thinking is often called **expansionism**, an alternative to classic reductionism. Whereas analytical thinking concentrates on **static** and **structural** properties, systems thinking concentrates on the function and behaviour of whole systems. Analysis gives description and knowledge; systems thinking gives explanation and understanding. With its emphasis on variation and multiplicity, rather than statistically ensured regularities, systems thinking belongs to the holistic tradition of ideas. However, what really differentiates this kind of thinking from ordinary linear cause/effect reasoning is that none of these concepts can be regarded as more primary than the other. A change can be initiated everywhere in an event cycle and after a certain time be read off as either cause or effect elsewhere in a system.

Systems thinking is a response to the failure of mechanistic thinking in the attempt to explain social and biological phenomena. As an attempt to solve the crisis of classical science it has formulated new approaches in scientific investigation. Primarily, it dates back to the 1920s when emergent properties in living organisms were generally recognized. Born in biology, it is easy to understand that the systems movement has acquired the major part of its terminology from that area when considering terms like autonomy, survival, etc.

It is now possible to note how the specific tools in the various areas have emphasized the different stages. The tools for the analysis were *par excellence* the microscope and the telescope, tools which must be considered to be reductionist promotive. The tools of the emerging systems age are designed to enhance synthesis and have often taken over the function of the classical laboratory. The computer has become a viable substrate for experimentation. Research in many fields such as nuclear, aerodynamics, biology, chemistry, etc. is now being simulated instead of actually performed. The particle accelerator combines analytic and synthetic properties in a kind of super microscope capable of the resolution of objects less than the diameter of the atomic nucleus. Geostationary or orbiting satellites give outstanding possibilities for the understanding of global phenomena and for the first time in history humanity has now the opportunity to look upon itself from the outside. Tools with the above-mentioned properties are often called **macroscopes**. Together these tools has done that which earlier only was intellectual experiments now can be real ones.

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The systems age

In the 1950s, with the introduction of computers, hydrogen bombs and space exploration, large-scale problems began to penetrate Western society. The traffic-system breakdowns, environmental disasters and the nuclear threat were immediately high on the agenda. Society was faced with *messes*, interacting problems varying from technical and organizational to social and political.

It was suddenly realized that many solutions were inadequate when applied to problems which no longer existed in their original form. Change itself, with its accelerating rate, was a major concern. Two hundred years of success for classical science and technology had created a form of development the long-term effects of which apparently were programmed to be devastating for humanity. ***Gerald Weinberg*** states in one of his books that 'science and engineering have been unable to keep pace with the second order effects produced by their first order victories'.

The following examples address some of the problems:

- deterioration of the human gene-pool, increasing allergies and diabetes
- deterioration of human epidemic environment, e.g. AIDS
- environmental destruction and climatological changes
- deforestation and desertification
- garbage accumulation, nuclear radiation, water, soil, and air pollution
- acidification, decreasing subsoil water and shrinking ozone layer
- decreasing biodiversity and extinction of species
- population explosion, criminalization, terrorism
- urbanization, unemployment, and proletarianization
- energy wastage and resource depletion
- motorization and noise pollution
- data pollution, lack of information and knowledge
- commercialization and cultural impoverishment
- mental corruption and drug abuse
- environmental ugliness with growing amounts of concrete and asphalt
- bureaucratization, passivization and dulling of the human intellect
- destruction of arable land with buildings, highways, mining districts, junkyards and minefields
- wars constantly in progress on several places in the world

Classical science, with its over-specialization and compartmentalization, had already proved its inability to handle problems of such tremendously increased complexity as in the above list. The interaction of system-variables are so interlinked to each other that cause and effect seldom can be separated. One separate variable thus can be both cause and effect. An attempt to reduce complexities to their constituents and build an understanding of the wholeness through knowledge of its parts is no longer valid. Not understanding that the wholes are more than the sum of their parts, scientists had assembled knowledge into islands, extending into an archipelago of disconnected data.

Not long ago, physics was regarded an archetype for all genuine science. A reductionary chain was envisaged where psychology was deducted to neurophysiology, neurophysiology to biochemistry, biochemistry to chemistry and this in turn to quantum mechanics. Today, modern biology has shown that this kind of reductionism is out of the question. Physics, chemistry and biology have united with each other into molecular biology — a new overarching description system separated from the area of both physics and chemistry.

Many scientists have now realized that the way they had embraced the world was not far-reaching enough to understand and explain what they observed and encountered. As ***Gary Zuchov*** (1979) says in his book *The Dancing Wu-Li Masters*: 'Their noses had been too deeply buried in the bark of a special tree, to be able to discuss forests in a meaningful way.' Against this background, the adaptation of science became systems thinking. This attitude was an answer to the inability of the mechanistic outlook to explain social and biological phenomena. It can be deduced from the 1920s when synergy-effects in living organisms began to be observed.

It was gradually accepted that systems are wholes which cannot be understood through analysis inasmuch as their primary properties derive from the interactions of their parts. Thus awareness grew that everything in the universe — including themselves — which seems to exist independently, was in fact part of an all-embracing organic pattern. No single part of this pattern was ever really separated from another. It was possible to catch a glimpse of a universality of systemic order and behaviour which characterized both living and non-living systems. That humans now had got access to some of the main design principles of the universe implied that they too were included in the drawings for some very significant ultimate purpose.

Earlier, the alternative to systemic intervention was to suffer the consequences, to endure whatever happened; scientists had too often waited for systems failures to see what these could reveal about the mechanism. Today function, not anatomy, is the main point. The important task is to solve problems in real life. To describe and understand were not values in themselves; their purpose was to enhance the capability for large-scale system prediction and control.

The technicians strove to have things work well, the social scientist to have things behave well. Science was to become more **ethical**, less **philosophical**. To do things, was considered to be more important than to think about them. In these circumstances emerged the new **interdisciplinary** and **holistic** approach. Here, holism was an attempt to bring together fragmentary research findings in a comprehensive view on man, nature, and society. In practice it was a search of an outlook to *see better*, a network to *understand better* and a platform to *act better*.

Without hesitation this had it roots in the wartime efforts and the special mentality of **operations research**. This 'emergency-discipline' handled military strategic decisions, resource allocations, optimal scheduling and risk analysis, etc. in a truly pragmatic way. Its aim was to do, to the best of human knowledge in a given context and with given time and resources, all in order to win the war. Its main guidelines were the following:

- It is not necessary to understand everything, rather to have it under control. Ask what happens instead of why.
- Do not collect more information than is necessary for the job. Concentrate on the main consequences of the task, the small details may rest in peace.
- Solve the problems of today and be aware that prerequisites and solutions soon become obsolete.

Operational research gave rise to the first successful methodology where the problem complex knot was disassembled into disciplinary parts and could be treated as one entity by different researchers.

In 1954, the International Society for General Systems Theory, ISGST, was founded. This society later become the International Society for Systems Science, ISSS. Two of the most prominent founders were ***Ludwig von Bertalanffy*** and ***Kenneth Boulding***. Although Bertalanffy had already formulated his ideas in the 1930s, he was not recognized until one of his now-classic papers on systems theory appeared in the American journal *Science* in 1950. Then, the idea that systems had general characteristics independent of the scientific areas to which they belonged was both new and revolutionary. Boulding in turn published his well-known system hierarchy in 1956.

The founding team of interdisciplinary scientists, had a shared interest in a universal science. They wanted to link together the many splintered disciplines with a **law of laws** applicable to them all. The following aims were stated:

- to integrate similarities and relations within science;
- to promote communication across disciplinal boundaries;
- to establish a theoretical basis for general scientific education.

Integration should be promoted by the discovery of analogies and isomorphisms and the new science should be a tool with which to handle complex systems. **Analogies** are explanations done by relating something not yet understood to something understood. **Isomorphism** exists when common characteristics, structures, formulas and form of organization are in accordance in different systems. That is, when formally identical laws governing the functioning of materially different phenomena exist. A partial accordance is generally referred to as **homomorphism**. The use of isomorphism made possible the indirect study of systems in terms of other systems (simulation) and the use of content-independent methods within different scientific areas.

Step by step a theory was established: the **General Systems Theory** or **GST**. As a basic science, it deals, on an abstract level, with general properties of systems, regardless of physical form or domain of application, supported by its own metaphysics in **Systems Philosophy**. GST provides a way to abstract from reality; simplifying it while at the same time capturing its multidimentionality. As an epistemology it structures not only our thinking about reality but also our thinking about thinking itself.

General Systems Theory was founded on the assumption that all kinds of systems (concrete, conceptual, abstract, natural or man-made) had characteristics in common regardless of their internal nature.

These systems could serve to describe nature and our existence. General Systems Theory is, however, not another discipline — it is a theory cutting across most other disciplines linking closely e.g. generalized concept of organization, to that of information and communication. GST uses various ways in classifying different types of systems — most of them offering an intuitive classification of systems ranked in increasing order of complexity. Here each level include, in some way, the lower levels but have its own, new, emergent properties. In the various levels of the taxonomy, it can be seen, that it is the relationships between components in the system and not the nature of its individual components, that proliferate its properties and behaviour.

Expressed in more precise terms, the goal of General Systems Theory can be specified as follows:

- To formulate generalized systems theories including theories of systems dynamics, goal-oriented behaviour, historical development, hierarchic structure, and control processes.
- To work out a methodological way of describing the functioning and behaviour of systems objects.
- To elaborate generalized models of systems.

As an applied science, GST became **Systems Science**, a *metadiscipline* with a content capable of being transferred from discipline to discipline. As such, it is knowledge regarding knowledge structures and attempts to add and integrate those aspects that seem not to be adequately treated in older science (but also to engage in continuous cross-fertilization of various disciplines). The management scientist *Ackoff* (1972) has defined the difference between the synthetic thinking of a metadiscipline and the analytical thinking of a discipline.

In systems science, the equivalent to the classical laboratory became the computer. Instead of designing experiments with real materials, the computer itself became a viable substrate for experimentation. The use of computers as instruments for calculations, simulations and the creation of a non-existing reality thus brought about a new phenomenon that is neither actual nor imaginary, a phenomenon or mode that was called *virtual*. The computer is a virtual reflection of a non-existing mechanical adding machine. To be precise, it is an abstract entity or process that has got physical expression. In itself, it is a simulation, a simulation which is not necessarily a simulation of anything actual. 'Virtual' is thus a mode of simulated existence, resulting from computation. When creating theories regarding the information world and complex living systems, different kinds of virtual worlds are necessary. There, the computer works as laboratory and in its digital universe artificial intelligence and artificial life is created. Research in many areas like astronomy, aerodynamics, biology, chemistry etc. is today performed by computers through virtual simulation. Such simulations have the advantage that unneccesary details regarding individual components can be excluded at which overall connections and complex interactions appear. By use of computers, new knowledge can be generated without dangerous and ecologically harmful full-scale tests e.g in the area of nuclear fission.

The aim of systems science was, however, not to replace, but to complement traditional science. The systems perspective naturally acquired greater significance with the growing complexity of all systems, including and embracing man. ***Gerald Weinberg*** (1975) says about systems science, that it has '…taken up the task of helping scientists to unravel complexity, technologists to master it, and others to learn to live with it.' **General systems thinking** based on systems theory became its hallmark with the aim of fostering generalists qualified to manage today's problem better than the specialists. Specific individual methods were developed, many of which included *modelling, simulation* and *gaming*. Focusing on problems of complexity, systems thinking applied as systems science has taken the task of being a science of modelling *par excellence*.

One of these methods, the **Systems Approach**, in reality an application of Systems Theory, operates in an integrated framework of modern organizational knowledge and management science. The Systems Approach is based on the fundamental principle that all aspects of a human problem should be treated together in a rational manner. It is an attempt to combine *theory*, *empiricism* and *pragmatics* and looks at a system from the top down rather than from the bottom up.

Another method, **Systems Analysis**, adopting a strictly systemic outlook on complex organizations, entered the scientific scene to ensure that no important factors in the structure were excluded. Problems of identifying, reconstructing, optimizing, and controlling an organization, while taking into account multiple objectives, constraints and resources were worked out. Possible courses of action, together with their risks, costs and benefits were presented. Systems analysis can thus be considered an interdisciplinary framework of the common problem-view.

An extension of this method, called **Anasynthesis**, was introduced with the implicit assumption that the more views one can apply to it, the better a problem can be understood. When using this method, *modelling*, *simulation*, *gaming*, *analysis* and *synthesis* are all applied to the development of a system. The method is used iteratively at both the macro and micro levels of large-scale systems. Normally, the outcome is more organized, structured and responsive to real-life requirements than the outcomes of other methods.

Then there is **System Engineering**, a method by which the orderly evolution of man-made systems can be achieved. Hereby the four Ms — **m**oney, **m**achines, **m**aterials and **men** — are used in making complex systems in their totality. Somtimes three more Ms are added, generated by information and denoting **m**essages, **m**ethods and **me**asurements.

A much-discussed method of a more theoretical kind is **System Dynamics**. Developed by ***Jay Forrester*** (1969) it uses dynamic computer models which change in a network of coupled variables. It has been employed to prognosticate the growth of the modern city (Urban dynamics), the development of Western industry (Industrial dynamics), and the global resource depletion (World dynamics).

Closely connected to the above-presented methods, and including them all, is the conviction that man is more the creator of reality than its discoverer. The future has become too complex to foretell or to be planned; it has to be created. That one cannot manage change, only be ahead of it is not relevant for systems thinking. Embracing such a pragmatic view on reality, **design** or **redesign** becomes the key concept of the systems perspective when it is about to change the world for the better by building new or improved systems. The vast majority of human systems have not been designed at all — they just happened. Design replaces the guesswork by model building and optimization. It is concerned with how things ought to be, with combining resources to attain goals. This involves processes necessary to *understand the problem*, to *generate solutions* and to *test solutions* for feasibility. Here, design is a creative process, questioning the assumptions upon which earlier structures have been built and demanding a completely new outlook. **Systems design** (or systems synthesis) is a formal procedure where human resources, artefacts, techniques, information and work procedures are integrated into a system in order to facilitate its performance.

Its working procedure rests on the following steps:

- The future environment of the system has to be forecasted.
- A model has to be build and used to simulate its function.
- From the simulation, a choice must be made as to what is the best (thus optimizing the system).

Systems design is the opposite of *systems improvement*, the policy of recovering old systems (***J. van Gigch*** 1978).

A more recent perspective when investigating systems is that of **teleology**, the doctrine that behaviour and structure are determined by the purpose they fulfil. Teleology does not exist in non-living nature but is universal in the living world. It indicates that systems are guided not only by mechanical forces but also move toward certain goals of self-realization. Here organizations and organisms have their own purposes, while artefacts, e.g. machines, serve the purpose of others but have no such purpose of their own. The search for knowledge can thus be founded both on the hunt for causes and purposes.

Complex systems can be studied from many points of view which are seen as complementary rather than competitive. The choice of theoretical approach depends mainly on the type of insight which is sought. A common quality of the named methods is the generation of knowledge necessary for the solving of the problem. The characteristic tools of the domain — computers, telecommunication networks, databases, etc. — are to be found in **informatics**.

One effect of the new approach was that subsets of traditional scientific areas amalgamated, forming new disciplines. A fresh example is the **science of complexity,** where biological organization, computer mathematics, physics, parallel network computing, non-linear system dynamics, chaos theory, neural networks and connectionism were brought together. In practice, complexity science is the study of the behaviour of large collections of simple units which have the potentially to evolve. This stimulated the definition of new reciprocal systemic qualities: complexity/simplicity and simulative/non-simulative. A new quantification of complexity was also introduced: the complexity of something should be defined as the length of the shortest possible description (algorithm) of this something. An alternative definition is in terms of the number of mathematical operations needed to solve it.

Laws of complexity generate much of the order of the natural world and its emergent properties. Complexity theory tries to describe how complicated rules sometimes produce simple and organized behaviour, e.g. the ability of living systems to become ever more organized. Its working methodology is non-reductionist: a system is viewed as a network of interacting parts, nearly all the fine details of which are ignored. Regularities and common patterns valid across many different systems are carefully examined. Of specific interest are those conditions which ensure the emergence of evolutionary, self-organizing and self-complicating behaviour. Complexity theory operates somewhere in the zone between the two extremes of complete order and complete chaos. To study complexity is to study systems and particularly the sort of systems behaviour which cannot be predicted from its individual components. Complexity concerns the system-fact that the whole always is greater than the sum of its parts. As a discipline its task is to come to grips not only with certain complex phenomena but also with the universal features of complexity itself.

Also, disciplines more directly related to systems science, such as cybernetics, bionics and C^3I, merit presentation. They make possible a broader perspective concerning the basic underlying principles of structure and behaviour in systems.

Cybernetics was defined in 1948 in a book by ***Norbert Wiener***: *Cybernetics or Control and Communication in the Animal and the Machine.* In cybernetics, living systems are studied through analogy with physical systems.

Bionics, the study of living systems in order to identify concepts applicable to the design of artificial systems, was introduced by ***Major Steele*** in 1958. The amalgamation of biology and technique is recognizable in the term. Bionics realizes physical systems through analogy with living systems. Cybernetics and bionics are often said to be the two sides of the same coin.

The acronym **C^3I** stands for command, control, communication and intelligence. During the past ten years, interest in the operations of social, military and business organizations has grown. Modern managerial systems are based on an interchange between people, organizational entities and technical support. The decision-making situation has often such an innate complexity that in the initial phase it is not possible to define what kind of information is important; the decider usually demands more information than will be useful.

In the extended acronym **C^4I^2** the extra **C** stands for computer and the extra **I** for integration, emphasizing the close interconnection between man and computer. Here, it is impossible to separate social from technical factors and the human being is always a part of the problem as well as a part of the solution. The adaptation man/machine is a key issue and the system has to be designed around man, his potential and his needs. In spite of access to high-tech decision support, a main point must be the training of human ability to handle the unexpected. Reality always tends to deliver a situation never met before.

Systems science applied as a problem solver in business organizations is sometimes called **management cybernetics**. As such, it is often occupied with design of an appropriate organizational structure which includes:

- Specification of the organization's sub-tasks and partition of work.
- Design of communication between the subsystems.
- Definition of areas of decision-making and authority.
- Design and development of control systems and co-ordination of efforts toward the organizational goal.

The efforts of management cybernetics are sometimes summed up with the acronym 'The Seven Ss'. These stands for **strategy, staff, style, skills, systems** (of communication), **structure** and **shared** values.

The emergence of the systems movement can now be recapitulated with some often-cited words of ***Kenneth Boulding*** from 1956:

> 'General Systems Theory is the skeleton of science in the sense that it aims to provide a framework or structure of systems on which to hang the flesh and blood of particular disciplines and particular subject matters in an orderly and coherent corpus of knowledge.'

To that must be added that one of the most important contributions of the systems area is that it provides a single vocabulary and a unified set of concepts applicable to practically all areas of science.

Let us finally remind ourselves that the systems age in which we are now living, is the result of the impact of the following five revolutions:

- The agrarian revolution — the product of the tribe's collective work, extended our food access.
- The scientific revolution — the product of European collective thinking, extended our knowledge capacity.
- The industrial revolution — the product of European collective technology, extended our musculature.

- The electronic revolution — the product of Global collective technology, extended our nervous system.
- The computer revolution — the product of Global collective synthesis, extended our intelligence.

*

Review questions and problems

1. Learned men of the scholastic era shared the belief that the nature of universe and time was possible to understand. In what field of knowledge could this conviction be studied?
2. What is the main difference between a teleological norm and a law of nature?
3. Why did science, as a human activity, have to declare itself independent, neutral, and objective from its earliest days?
4. In the deterministic era, the question of free-will was considered irrelevant. Why?
5. What are the most significant metaphysical presumptions behind the concept of the laboratory?
6. The scientific method is associated with five methodological steps. Describe the last step and explain its importance.
7. The old Greek mathematician Pythagoras once said: 'Omnia mutantum, nihil interit' (Everything changes, nothing is lost). How can this be associated with the laws of thermodynamics?
8. Quantum theory has been used in an attempt to explain the classic body/mind problem. How does the train of thought run?
9. Gerald Weinberg states that 'science and engineering have been unable to keep pace with the second order effects produced by their first order victories.' Give some examples of particularly devastating secondary effects influencing modern society.
10. Has systems theory been successful in formulating a law of laws applicable to all scientific disciplines? If so, how does one of these laws read?

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GENERAL SYSTEMS THEORY

IDEAS & APPLICATIONS

by **Lars Skyttner**

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The world in which classical positivistic science and technology obtained great success has vanished. However, the way of thinking promoted by that epoch still lingers in our social consciousness, sometimes as a burden. To conquer the shortcomings of classical analytical science in the modern, ever more complex world, systems theory and its applications within systems science present an alternative to old paradigms.

Systems theorists see common principles in the structure and operation of systems of all kinds and sizes. They promote an interdisciplinary science adapted for a universal application with a common language and area of concepts. This approach is seen as a means of not only overcoming the fragmentation of knowledge and the isolation of the specialist, but also finding new solutions to problems created by the earlier "solution of problems".

This book introduces the systemic alternative. It is divided into two parts. The first is devoted to the historical background of the systems movement, and presents pioneering thoughts and theories of the area. Basic concepts of general systems theory with well-known laws and principles are discussed, as well as related topics like cybernetics and information theory.

The second part deals with some of the common applications of systems theory within systems science, such as artificial intelligence, management information systems and informatics. An attempt is made to predict the future of systems theory in a world apparently becoming fragmented and integrated at the same time.

To engage oneself in systems theory and its striving towards an applied universal science is a highly cross-scientific occupation. The reader will come into contact with many different academic disciplines, and consequently the possibility of an all-round education — something particularly needed in our over-specialized world.

Captain Lars Skyttner *began his career as a naval radio officer in the Far East. After some years at sea, he became a Swedish army officer and trained in the the Army Air Force where he served as an aircraft pilot. Leaving pilot service, he was commanded as UN infantry officer in the Middle East as manager of Military Telecommunications. On returning to Sweden, he started his academic career and received a PhD in Systems Science from the University of Stockholm.*

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