An Introduction to Linguistic Synergetics

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Cambridge Scholars Publishing

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This book first published 2018

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-5275-0570-7
ISBN (13): 978-1-5275-0570-4

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PREFACE

Why does language change over time?

What are the triggers and mechanisms of changes on different language levels, such as the phonemic level, the morphemic level, the lexical level, and the syntactic level? Why is lexis subject to rapid changes and innovations while syntactic constructions tend to retain a certain stability over centuries? How did it come about that within a few centuries the English language has changed its grammatical system from synthetic to analytical? These and some other questions inspired by my interest in the theory of language development have motivated me to look for a new approach to the subject under consideration.

This book is an attempt to study language development within a synergetic perspective. Synergetics is defined as a theory of self-organising complex systems of various ontologies. It calls for a macroscopic approach (H. Haken), dealing with complex systems from a unifying point of view. Synergetics has suggested a new approach to the object of analysis, new methods of investigation, and a new wider repertoire of concepts and categories aimed at helping the researcher reveal new aspects of the phenomena investigated. The new approach and methods, which were primarily developed in physics, chemistry, and biology, have also proved valid in philology due to the fact that human language has the same features as any synergetic system. Their application to the study of language has given birth to a new trend in linguistics that was given the name of linguistic synergetics, or linguosynergetics.

The first chapter of this book, "*Synergetics: The Study of Complexity*", contains a brief survey of the historical background of synergetics, and discusses its status and main tasks. It also provides an introduction to some basic concepts of synergetics and reveals its interdisciplinary character.

The second chapter seeks an answer to the question, "*What is Linguistic Synergetics*?". It considers the methodological and conceptual basis of linguistic synergetics, its topical space, aims and tasks. This chapter also provides an overview of language as a synergetic megasystem and defines its fundamental features from the synergetic perspective.

The third chapter, "*Diachronic Synergetics: A Few Notes on the Development of the English Language*", offers a novel conceptual perspective on the history of English. It starts with the discussion of the problem of appropriate periodisation of the history of the English language. It then focuses on phonetic changes, as well as historical changes within the structure of words, looked at from a synergetic angle.

The fourth chapter, "*A Synergetic Model of Language Development*", represents the evolution of the English language as a synergetic process involving a synchronisation of tempo-worlds in the grammatical system, changes of the parameter pattern of the language system and, finally, a typological shift as a change of the states of the language mega-system.

Excerpts from essays written in Russian or Ukrainian are presented in this book in free translation.

ACKNOWLEDGEMENTS

I would like to express my appreciation and warm thanks to Prof. Irina Kolegayeva (Odessa), Prof. Isabella Buniyatova (Kiev), Prof. Lidia Pihtovnikova (Kharkov), Prof. Andrew Levitsky (Moscow) and all my colleagues in the English Department at Odessa I.I. Mechnikov National University (Ukraine) for being supportive.

I feel extremely lucky to publish this book with Cambridge Scholars Publishing. Victoria Carruthers, Theo Moxham, Helen Cryer, Christine von Gall, Adam Rummens and Amanda Millar have been the greatest pleasure to work with and have been helpful with every detail in the preparation of this book's physical manuscript. I would like to thank them for their advice, their courtesy, and their patience with me throughout the whole process. Special thanks go to John Ingamells for his incisive comments when editing this manuscript.

I also owe a great debt to my precious family for their unending patience and encouragement.

I reserve my deepest gratitude for my Dad, to whom this book is dedicated.

CHAPTER ONE

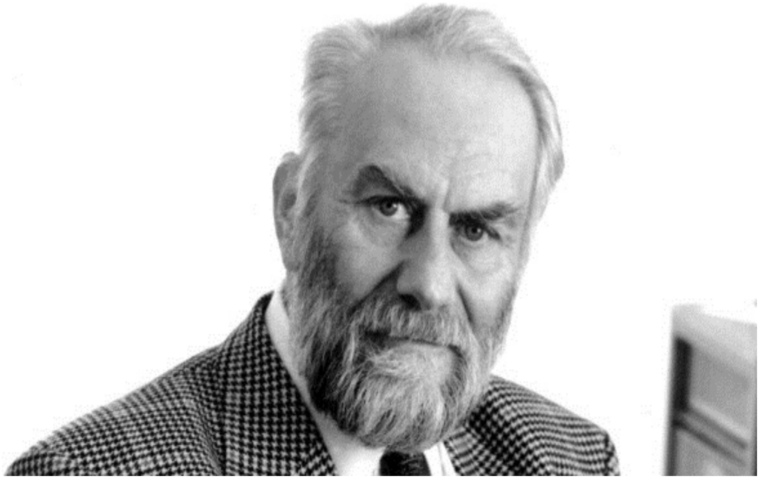
SYNERGETICS: THE STUDY OF COMPLEXITY

Synergetics within a Historical Retrospective

The early years of the 20th century witnessed a revival of the concept of 'system' known since ancient times. Thanks to a great number of scientific discoveries, the rise of new scientific disciplines (such as genetics in biology, thermodynamics and quantum mechanics in physics and others), as well as rapid development of new technologies, significant changes were brought to our understanding of the system and its ubiquity.

The outer world began to be seen as a dynamic conglomeration of systems – biological, chemical, physical, social, etc. Researchers were eager to construct a comprehensive scientific view of the world based on laws common to both organic and inorganic nature, or, put differently, to create a new complex systems paradigm. New scientific theories were suggested (such as General Systems Theory, Quantum Theory, Irreversible Thermodynamics Theory, Instability Theory, Dynamic Chaos Theory, Catastrophe Theory, Phase-Transition Theory, the Theory of Bifurcations, the Theory of Autowave Processes, the Theory of Oscillation, to mention just a few) within which new concepts and methods of investigation were developed, which later provided a foundation for synergetics as a unified approach to various complex systems study.

Cybernetics is also considered a precursor of synergetics. In the words of Norbert Wiener (1894 –1964), the founder of this interdisciplinary science, cybernetics is a theory of 'control and communication in the animal and the machine'. The word is of Greek origin meaning 'governance', or 'government'. Cybernetics focused on negative-feedback-based complex systems of causal-chain circularity, i.e. automatic systems capable of restoring their stability within a desired range regardless of any disturbances. It is within cybernetics that the notion of '*homeostasis*', meaning invariability and balance of states, as well as internal steady-state, came to be applied not only to living beings, but also to technological systems. This notion is seen as one of the most important aspects of a system, necessary for maintaining its stability and functioning.



Hermann Haken

Unlike cybernetics which studies relatively balanced, stable and homeostatic systems, synergetics focuses its attention on hysteretic, i.e. evolving, positive-feedback-based complex systems. The notion of '*hysteresis*' (from Greek 'lagging behind') means a delay in the production of an effect by a cause [134: 478]. In other words, it is a 'history dependence' of a system. To predict such a system's behaviour, it is necessary to know the 'history' of all external influences upon the given system.

The term '*synergetics*' (from Greek 'coherent action') was coined by the German physicist Hermann Haken in the mid-1970s to name a science of complexity, dealing with principles of emergence, self- organisation and self-regulation of complex systems of various ontologies – either man-made (artificial) or natural (self-organised).

What, then, is understood by 'complex systems'?

A naïve assumption is based on a description of a complex system as having numerous components connected to one another. However, this interpretation is insufficient for research purposes: "A modern definition is based on the concept of algebraic complexity" [85: 4], i.e. it includes a sequence of data describing both the interconnected network and cooperativity of the system's elements and their complex behaviour.

Robert C. Bishop considers it more informative to characterise complex systems phenomenologically and lists the following most important features in these characterisations:

- *Many-body systems*. Some systems exhibit complex behaviour with as few as three constituents, while others require large numbers of constituents.
- *Broken symmetry*. Various kinds of symmetries, such as homogeneous arrangements in space, may exist before some parameter reaches a critical value, but not beyond.
- *Hierarchy*. There are levels or nested structures that may be distinguished, often requiring different descriptions at the different levels (e.g., large-scale motions in fluids vs. small-scale fluctuations).
- *Irreversibility*. Distinguishable hierarchies are usually indicators of, or result from, irreversible processes (e.g., diffusion, effusion).
- *Relations*. System constituents are coupled to each other via some kinds of relation, so are not mere aggregates like piles of sand.
- *Situatedness*. The dynamics of the constituents usually depend upon the structures in which they are embedded as well as the environment and history of the system as a whole.
- *Integrity*. Systems display an organic unity of function which is absent if one of the constituents or internal structures is absent or if relations among the structures and constituents are broken.
- *Integration*. Various forms of structural/functional relations, such as feedback loops couple the components contributing crucially to maintaining system integrity.
- *Intricate behaviour*. System behaviour lies somewhere between simple order and total disorder such that it is difficult to describe and does not merely exhibit randomly produced structures.
- *Stability*. The organisation and relational unity of the system is preserved under small perturbations and adaptive under moderate changes in its environment.
- *Observer relativity*. The complexity of systems depends on how we observe and describe them. Measures of, and judgements about, complexity are not independent of the observer and the choice of measurement apparatus [63: 111–112].

A complex system manifests its phenomenal richness and, consequently, demands new ways of scientific analysis, as well as a new framework of categories. Synergetics suggests integrity of methods elaborated in various disciplines and a variety of models to represent the complexity of organic and inorganic systems.

Successful application of the concepts and methods of the synergetic approach to the description of biological, physical, historic, social, and even economic phenomena has revealed similarity, if not universality, of principles of evolution of complex systems. As a result, synergetics has made it possible to launch a wide variety of interdisciplinary interrelationships, among them mathematical physics, mathematical history, social government, neurosynergetics, meteorology, geodynamics, prognostics, to name a few. The new disciplines, in their turn, require specialists with a profound knowledge of complex systems methodology. Otherwise, as Cliff Hooker points out, people whose education does not include relevant competency in complex systems are excluded from science, policy, and large-scale business, or they find themselves increasingly dependent on those who have such competency [89: 6].

Nowadays, the necessity of integration of different sciences calls for no argument and most scholars agree that the future of science lies within interdisciplinary research of complex systems [see, e.g. 30:8; 48:235; 88; 89]. In the words of George Malinetsky, the 21st century is bound to become a century of a re-establishment of holism and a deep understanding of common problems [39: 42]. It is interdisciplinary orientation that helps scientists think globally, i.e. beyond the borders of particular disciplines.

On the Status and Tasks of Synergetics

The review of available special theoretical literature on synergetics – articles, essays, and manuscripts – has revealed an absence of unanimity among scientists as to the status of synergetics.

Some authors speak of synergetics as a *new style of scientific thinking*, identified with non-linear thinking that, in a theoretical plane, plays the role of a certain *meta-science*, studying the common principles as if dissolved in particular disciplines [34]. For others, synergetics is a *theory* of evolution and self-organisation of complex systems of the world that lays a common basis for a description of mechanisms of emergence of various innovations [17; 32; 33]. Still others consider synergetics to be a *scientific mainstream* aiming at uniting natural sciences and humanities on the basis of a common method of generalisation [48]. There are many who regard synergetics as *a new scientific paradigm* [3; 5; 28–31]. Synergetics is also seen as *"an interdisciplinary approach* founded on intersection of the subject knowledge, mathematical modelling and philosophical reflection" [36:17], or even as *an interdisciplinary methodology* for explaining the emergence of definite macroscopic phenomena due to non-linear interrelationships among microscopic elements in complex systems [35: 26].

A wide diversity of understanding the status of synergetics is demonstrated in Fig. 1.

Moreover, some scholars define synergetics differently in their different articles or even within the same article. Such a situation can be explained by the multi-dimensional character of synergetics. Thus, Helena Knyazeva in [32: 70–71] speaks of the following dimensions of synergetics:

- *A scientific dimension*. Synergetics is defined as a peculiar mainstream of scientific investigations focusing on the study of complexity, non-linearity, and chaos, on outlining and mathematical modelling of the so-called blow-up stages described by the hyperbolic law.
- *A philosophical dimension*. Here the focus is shifted to explanatory possibilities and an interdisciplinary character of synergetics. The author warns against reducing synergetics to particular disciplines, such as physics or chemistry within which it emerged. On the contrary, synergetics studies universal principles of self-organisation, as well as the emergence and co-evolution of complex systems.
- *A methodological dimension.* This consists of drastic changes taking place in the conceptual network of man: "There appears a new synergetic view of the world – evolutionary, non-linear and holistic. The old paradigm is being broken by a conceptual shift from 'being' to 'becoming', from stability and equilibrium to instability and non-linear phase transitions, from order to chaos serving as a basis for innovative changes in complex systems."
- *An epistemic dimension* of synergetics is seen in the application of models in the study of cognitive and creative processes.
- *A social dimension* of synergetics is perceived in the application of synergetic models in social studies, including prognoses of social processes development. Such models are believed to serve as the foundation for further scientific research of the so-called non-linear methods of social government.
- *A prognostic dimension* of synergetics. It is claimed that synergetics can become a novel methodology in the study of the future (prognostication).

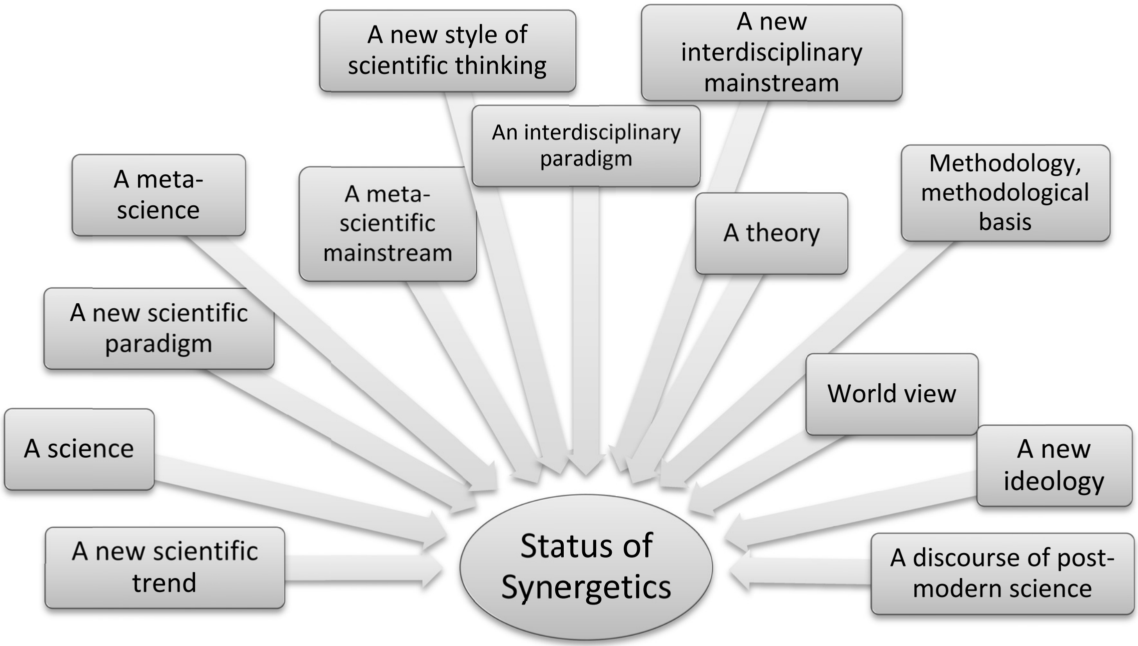


Fig. 1.1 Understanding the Status of Synergetics

I think that synergetics has one more dimension, let's call it *humanitarian*. It concerns the application of the synergetic methodology to the study of human language as a complex system. This dimension is close to the epistemic one, but unlike the latter dealing with man's cognitive *activity*, the former focuses on complex systems as a *result* of such activity and studies further the behaviour and development of constructed complex systems.

All of the above proves that synergetics as a unified theory of complex systems is multi-dimensional, which, on the one hand, makes it hard to strictly define its status, but, on the other, outlines the **main tasks** of this theory. They are connected with:

- the study of a wide variety of states of an open, dynamic, non-linear self-governed system in order to obtain the whole spectrum of possible structures of a given complex system in a non-linear environment;
- the study and modelling of self-organisation processes (phase shifts) of a synergetic system. This presupposes analysis of existing attractors of the system;
- singling out and description of the system's 'life' stages within a non-linear environment – emergence, functioning, and decay;
- reanalysis of the concepts of 'chaos', 'order', and 'chance' in the light of the synergetic methodology. This will enable a scientist to predict possible alternatives in the development of a complex system;
- description of a synergetic system as a unity of co-evolving complex subsystems of various 'ages' [see works by H. Knyazeva and S. Kurdyumov]. A synergetic system is heterogeneous not only because it consists of various subsystems and elements of different types: it may include (and it usually does!) components at various stages of development. A widely-known example is the human body: on the one hand, it contains a coccyx, a rudimentary tail which is of little use in the life of a body; and on the other hand, the cerebral cortex which has no analogy in the organic world.

Scientists strongly believe that the application of principles of co-evolution of complex systems, as well as principles of non-linear development of open dissipative environments, will result in the formation of a new efficient approach to the solutions to global problems facing mankind and contemporary science [3].

Needless to say, the common feature of all synergetic systems is their uniqueness: the Universe, our life on planet Earth, the languages and cultures of the peoples of the world, ecosystems, and so on are unprecedented and one-off. Consequently, man's responsibility for his actions (most of which are irreversible) increases. I cannot but agree with George Malinetsky who says: "We must think, foresee and plan our actions in this only world where we live and in this only life at our disposal. It is a challenge to many sciences" [37: 21].

All things considered, synergetics helps us understand the principles of complex systems, predetermining our present day and our tomorrow.

The Peculiarity of Synergetics

Synergetics is regarded as a new stage in the development of the theory of systems with special emphasis on issues of evolution and phase shifts. The methodological peculiarity of synergetics consists in the study of the development processes as a multi-stage self-regulation of a certain structural unity. Synergetics has changed our world outlook by representing reality as open, ever-changing, non-linear, and infinite in the choice of alternatives of further development.

In the words of the Nobel Laureate in chemistry (1977) Ilya Prigogine, synergetics has changed our perception of matter and its role in the Universe: 'The matter is no longer a passive physical substance, as it was described within the mechanical paradigm. It is also characterised by a spontaneous activity. The new view of the world differs drastically from the traditional one; we may as well speak of a new dialogue of man and nature' [43: 37, 50].

Synergetics has made it possible to look at chaos differently. Coming from mythology, chaos is traditionally associated with instability, disorder, destruction, and mess. In other words, the very concept of 'chaos' has always been used with a decidedly negative connotation. By contrast, the notion of 'order' has always been perceived of being a complete antonym of 'chaos', something that is good, stable, and purposefully desirable.

In the synergetic paradigm the notion of 'chaos' acquires some additional shade of meaning. Chaos is not just destructive, it is constructive as well! Chaos is seen as a mechanism of self-organisation, a mechanism of switching the system's states, or regimes of existence, a mechanism of transition to a new equilibrium. It is a way of renewing the complexity in nature.

Ilya Prigogine

Lately, the concept of 'chaos' has attracted special attention from researchers studying its peculiarities, its various degrees and limiting features in different environments. The theory of dynamic chaos aims at disclosing mechanisms of emergence of new levels of structural organisation, when random fluctuations in unbalanced states lead to the formation of attractors in a non-linear environment and to the subsequent emergence of new order parameters. As Vyachslav Stepin notes, the traditional philosophic concept of 'a dialectical leap', meaning a transition to a new quality in the development of a certain system, used to be ignored in the previous scientific paradigm, but only in synergetics has it come into focus [46].

Synergetics also sheds new light on one of the fundamental issues of philosophy, namely the problem of the correlation of the part and the whole. This problem seems to be connected with the issue of the co-evolution of integral parts of a given system. It is well known that the whole is not a mere sum of its components. Water, ice and vapour are three forms of existence of one and the same substance. Other examples – diamond and graphite – have the same components but different physical and chemical characteristics. The 'mystery' can easily be explained by the specific network of relationships among the system components.

It was within the synergetic paradigm that scientists paid attention to another phenomenon: an open dynamic complex system consists, as a rule, of parts that are at different stages of their development. This is true with a language system, too. Take, for example, a word-stock of any living language, and you will find new words and expressions alongside obsolete ones.

Synergetics is seen as a specific theoretical and methodological platform, systematising numerous fragments of knowledge about the external world obtained by science and integrating them into a comprehensive image of the world. A synergetic view of the world represents the latter as capable of self-organising from parts into unity. This calls to mind a hologram, in which the whole can be restored from any of its fragment. The holographic model of the world is supported by a philosophical understanding of the wholeness of the physical matter and may be regarded as a next stage in the never-ending evolution of the Universe. The Universe constitutes a total dynamic superstructure of limitless variety of criss-crossed powerful mega-systems developing in a non-linear way and changing according to their own inner laws and purposes.

Nowadays, the methodology of science undergoes significant changes, concerning, first of all, the paradigm shift – from ‘destructive analysis’ to ‘constructive synthesis’. A unified theory of complex systems is being born.

Key Concepts of Synergetics

A new approach to the study of complex open dynamic systems facilitates the introduction of new terminology, as well as a reconsideration of ‘old’ concepts and notions.

The necessity for strict definition of terms widely employed (often metaphorically) in contemporary scientific literature is beyond argument. The use of different terms to designate the same phenomenon is not rare, especially in articles by scientists working in geographically dispersed countries (that is why the significance of personal participation in international conferences and accessibility to the proceedings of such forums cannot be underestimated).

Below are listed the key concepts of synergetics. However, this is not an exhaustive list but it includes only the notions also employed in linguistic synergetics (see Chapter 2), namely: a closed/open system, linearity/non-linearity, self-organisation, dissipation, order (control) parameters, fluctuations and bifurcations, stability (equilibrium)/instability, an attractor, a fractal, and coherence.

Let us consider them in brief, in order of appearance.

A closed/open system

A system is usually defined as a set of hierarchically organised components (elements, parts, subsystems, etc.), having spatial and temporal boundaries and existing in a certain environment. If a system interacts with its environment by exchanging information, energy, and matter with the latter, then such a system is called open. An open system is only able to function with energy from its environment. By contrast, a closed (or isolated) system does not exchange energy or matter with its environment. Most natural systems are open. So are social systems.

In what follows, we are going to discuss open systems and their properties.

Linearity/non-linearity

In the paradigm of stability and equilibrium, **linearity** was an idealistic image of simplicity and cause-consequence determination displayed in the system's proportional reaction to the external disturbance. It deals with the homeostasis of a system and agrees with the superposition principle. The word 'linear' comes from Latin *linearis* meaning *resembling a line*, as a straight line is a graphical representation of mathematical solution of the relevant differential equations. Designed, i.e. human-made, systems, for instance, telecommunications and signal processing, hydrodynamic models, electricity and optics models, are all linear and can be represented by linear equations.

However, most systems of the world are **non-linear**, chaotic and hardly predictable. In other words, their behaviour is not determined by certain initial conditions, nor can it be defined by the familiar principle "If X.., then Y...". The behaviour of such systems can be described algebraically by specific equations with a few or many unknowns. The graphical representation of the mathematical solutions of such differential equations is a curve.

The synergetic paradigm focuses on non-linearity as a more important notion out of the two in the 'linear'/'non-linear' opposition. Non-linearity is recognised to be primary as compared with linearity. It helps us see the world as much more complex from the view of systems' behavioural patterns. It also allows the definition of a hierarchy of complexity levels, and envisages investigations into asymmetry, regularity and irregularity.

The term ‘non-linearity’ came into the conceptual network of synergetics from mathematics, where it is defined as a particular type of equation with numerous variables and unknowns, which widen the spectrum of possible solutions depending upon the variables and/or coefficients.

The synergetic paradigm outlines a philosophical aspect of non-linearity which is revealed in the set of alternatives of evolution routes and change rates depending upon the environment characteristics, as well as the irreversibility of evolution [30:50]. As is seen, the notion of *non-linearity* has widened its meaning from the narrow, specialised term to a philosophical concept. Nowadays, non-linearity is a conceptual nucleus of the synergetic paradigm which is also referred to as a paradigm of non-linearity [ibidem, p.48].

Self-organisation

A non-linear environment is considered a necessary condition for self-organisation of a synergetic system. Sequences of acts of self-organisation in a complex system constitute a ‘history of life’ of the given system, its evolution.

In synergetics, self-organisation is both a process and a result of coherent interaction of numerous components and parts of a system aimed at regulating the inner structure of the system. Self-organisation is characterised by spatial, temporal, spatial-temporal and/or functional shifts and rearrangement of the given system. Correspondingly, systems which can acquire macroscopic spatial, temporal, or spatio-temporal structures by means of internal processes without specific interference from the outside, are called self-organising systems [85: 69]. Self-organising systems are found both in organic and inorganic matter.

The phenomenon of self-organisation of complex systems has been successfully studied in physics, chemistry and biology. While researching complex self-organising systems, a Belgian physical chemist, Ilya Prigogine, defined dissipative structures and formulated Dissipative Structure Theory; a German physicist, Hermann Haken, introduced the notions of ‘order parameters’ and ‘slaving principle’.

The term ‘**dissipation**’ is used to designate irreversible processes of internal energy degradation and/or transformation in thermodynamic open systems. A dissipative system exchanges energy and matter with its environment. Examples of dissipative systems are diffusion, friction, emanation, cyclones, hurricanes, turbulent flows, lasers, and so on. Ilya

Prigogine also coined the term ‘dissipative structure’ to denote a dissipative system having dynamic regimes and characterised by anisotropy.

Scientists working in the synergetic paradigm distinguish between microscopic and macroscopic levels of description of a system. The microscopic level includes investigating into elementary components and their behaviour within the given system, while the macroscopic level is a description of the whole system’s dynamics as a result of its external interactions with the outer world. Needless to say, macroscopic changes in a complex system, whereby new structures or new functions occur, are the focus of special attention: “This restriction to qualitative, macroscopic changes is the price to be paid in order to find general principles” [85: 13].

H. Haken suggests describing the macroscopic pattern of a system with the help of certain macroscopic variables called the **order parameters**. The latter govern the behaviour of the microscopic elements and parts by the ‘slaving principle’: “In this way the occurrence of order parameters and their ability to enslave allows the system to find its own structure” [ibidem].

Order parameters are not abstract mathematical notions; they are physical characteristics of a certain complex system. Changes within the parameter pattern may signal a structural change of the complex system, and vice versa. Order parameters are considered the key to the explanation of the system’s behaviour, for they allow reducing complexity of the system under study, which makes it easier to understand the ways of a complex system: “The use of order parameters at the macrostate level means an essential reduction of modelling complexity at the microscopic level which could not be analysed in all details” [32: 80; 35].

Fluctuations and Bifurcations

A fluctuation is understood as a temporary stochastic change of a characteristic of a system or continual switching from one point to another, which may cause a certain variety in the system’s dynamics, including even the loss of stability.

Fluctuations can bring the system to a critical point called ‘bifurcation’, i.e. a peculiar branching or junction of the system’s possible regimes of existence. The term ‘bifurcation’ was introduced by the French mathematician and philosopher of science Henri Poincare in 1885.

Bifurcations are of two main groups – local and global, leading the system to local or global changes, correspondingly. “There are many dynamically different ways in which this can occur, broadly classified as either local – where the form changes continuously as some dynamical parameter or parameters continuously vary – or global changes that involve more complex shifts. Among the latter are phase transitions (e.g. gas to liquid, liquid to solid, or reverse), including critical point transitions (e.g. simultaneous transitions among gas, liquid and solid states), where changes can be discontinuous and incomputable, essentially because fluctuations on every scale up to that of the whole system are simultaneously possible" [89: 26–27].

Bifurcations are called 'soft' if they lead the system to a new state smoothly and steadily; and 'catastrophic' if the transition occurs suddenly. In any event, bifurcations characterise the instability of the system's state.

Stability/Instability

Instability is a peculiar state of an evolving complex system in which it reveals sensitivity to external disturbances. By contrast, stability is a state of equilibrium of a system.

Scientists distinguish between static and dynamic equilibria: "Static equilibria require no energy input or output to persist, e.g. a crystal at rest. Dynamical equilibria typically require an irreversible ordered energy (negentropy) flow to sustain them, e.g. water flow to sustain the wave structure of river rapids, together with appropriate waste (degraded or entropic) outputs, e.g. turbulent water. For living systems there is water, food and hydrogen or oxygen input flow to sustain them and heat and chemicals as waste outputs" [88: 23].

If a system is instable, then the slightest fluctuations may lead through irreversible bifurcations to drastic changes in the structural organisation of the system and, thus, to increasing complexity of the system's dynamics on the whole [35: 131]. However, the same fluctuation may be ignored by the system if the latter is at equilibrium.

Instability is one of the principal concepts in synergetics. Moreover, according to Dmitry Chernavsky, it should be considered the most important one: "They say synergetics is a science of non-linear processes, it is correct, but it is not foremost. They say synergetics is a science of far-from-thermodynamic-equilibrium systems, and it's true, but it's not foremost, either. They say synergetics is a science of self-organisation of evolving systems, and it is so. However, since instable processes underlie self-organisation, we may say that synergetics is a science of instable processes. That is true. Moreover, that is foremost" [48: 271].

Attractor

An attractor is another concept that came to synergetics from natural sciences and is widely used in the description of evolving open systems. It denotes a state or a behaviour pattern towards which a dynamic system tends to evolve, regardless of the starting conditions of the system and is represented as a point or orbit in the system's phase space [132].

James A. Coffman suggests the following interpretation of this notion: "The total set of positive (activating) and negative (inhibitory) interactions within a system can be described as a 'regulatory network' that constrains the development of information in a logical (and hence predictable) manner. An important property of such networks is that they are often the source of self-organising 'attractors'. An attractor, which is a stable state towards which a developmental trajectory is inexorably drawn (e.g., the phenotype of an organism), is established by the regulatory network architecture, that is, by the set of logical rules (positive and negative interactions) that regulate the development of information within a self-organising system. In essence, an attractor is a final cause accessed by the regulatory network, which is in turn a formal cause established by organisation that developed via the selective agency of autocatalytic cycles" [72: 300].

It is assumed that an open non-linear environment conceals in itself a set of certain structural types (attractors). Once a system has chosen one of the possible trajectories of evolution, the other routes, so to speak, are closing down. Since the environment itself is subject to changes, then the whole set of potential ways of development can change as well. That is why certain attractors may never come to life [see 32: 110].

The theory of dynamic systems distinguishes the following three types of attractors: 1) point; 2) periodic, and 3) strange, or chaotic (see Fig. 1.2 below).

A point attractor is a single-state attractor.
A periodic attractor includes a set of states with definite orbits.
A strange attractor is characterised by a chaotic, never-repeated behaviour.

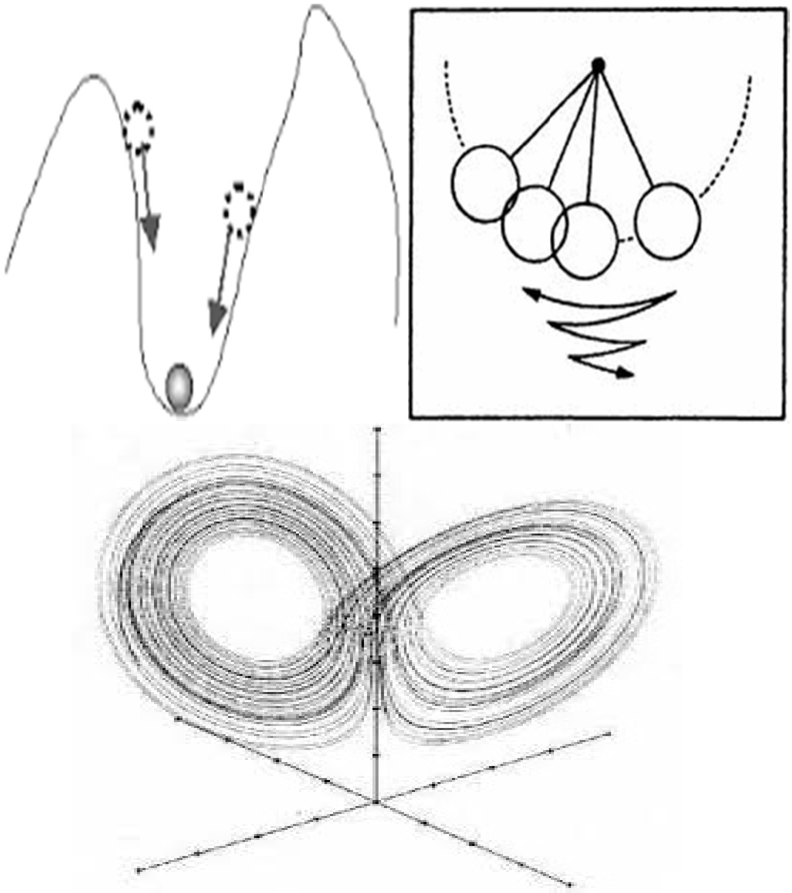


Fig.1.2 Types of attractors

Fractals and fractality

The term 'fractal' was introduced by the French and American mathematician Benoit Mandelbrot (1924–2010) in 1975 to describe a pattern of self-similarity at every level and/or scale of the structural organisation of a complex system. The word is of Latin origin meaning 'broken'.

The concept of self-similarity is usually illustrated using the analogy of zooming in with a lens on digital images to uncover finer, previously invisible, new structures. Within fractals, zooming in reveals the same pattern, not a new structure: a segment of a fractal-scaled structure is a replica of the whole structure. In other words, one and the same pattern is repeated at various levels of the structural organisation.

Benoit Mandelbrot

Scholars agree that fractals are difficult to define in an exact way, although self-similarity is recognised as the basic feature of fractals. However, self-similarity is not a homogeneous phenomenon. Kenneth Falconer (2003) points at the following types of self-similarity:

- *Exact self-similarity* that is identical at all scales; e.g. geometrical fractals, such as Koch snowflake;
- *Quasi self-similarity* that approximates the same pattern at different scales or may contain small copies of the entire fractal in distorted and degenerate forms; e.g. the Mandelbrot set's satellites are approximations of the entire set, but not exact copies.
- *Statistical self-similarity* that repeats a pattern stochastically across scales; e.g. randomly generated fractals, or natural fractals, such as the coastline of Britain.

- *Qualitative self-similarity* is revealed in a time series.
- *Multifractal scaling* that is characterised by more than one fractal dimension or scaling rule.

There are several types of fractals, among them being mathematical (geometrical) and natural. Mathematical, or geometrical, fractals are abstract, computer-generated and practically infinite. B. Mandelbrot (1983) described geometric fractals as being ‘a rough or fragmented geometric shape that can be split into parts, each of which is (at least approximately) a reduced-size copy of the whole’.

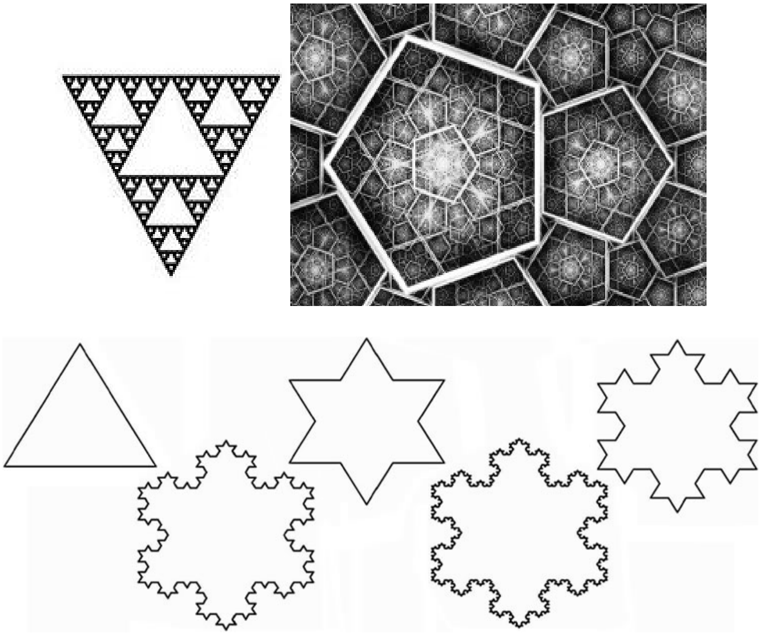


Fig.1.3 Geometrical fractals

In nature fractal patterns can be found as well – clouds, corals, trees, mountain chains, river basins, a blood system and lungs in living organisms, etc., are all fractal-scaled.

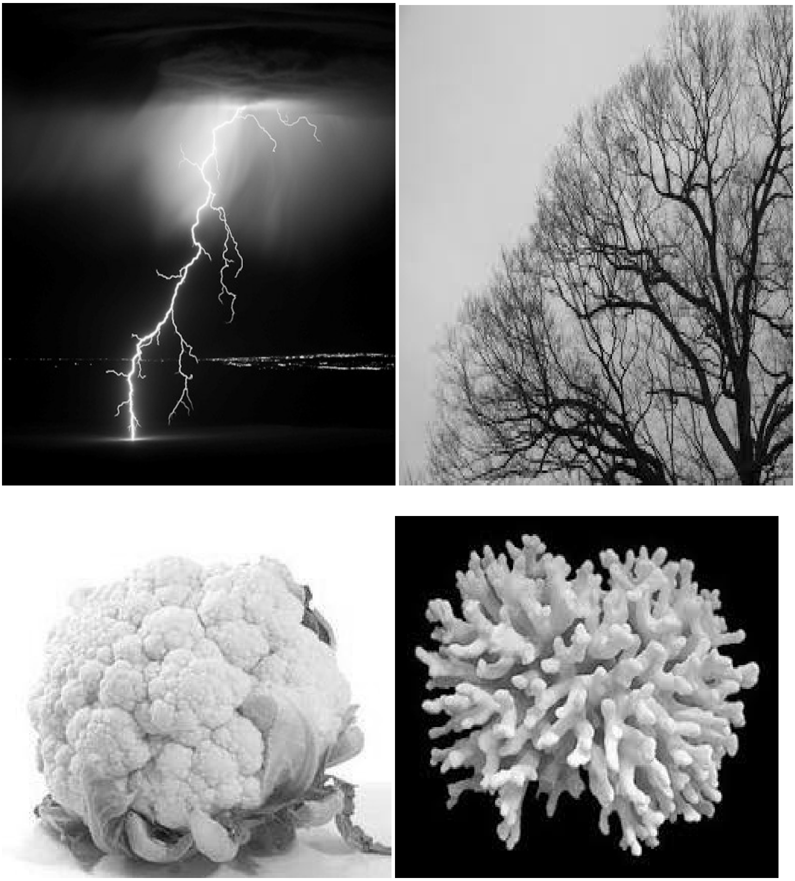


Fig.1.4 Natural fractals

Why are fractals so numerous in the natural world?

To find an answer to the question, scientists focussed their attention on a most important peculiarity of fractals, namely their ability to considerably compress the volume of the object having a self-similar structure. In other words, a fractal-patterned object takes up a smaller space but at the same time its length tends to infinity (for example, a coastline can be measured with the help of fractal geometry).

One of the ways to cognise various phenomena of the natural world is the so-called ‘fractal analogy’ with the help of which synergetics explains the fact that certain structures are repeated at different stages of the system’s evolution.

Coherence

This term came to synergetics from physics where it is used to denote the ideal property of waves that enables temporally and spatially constant interference.

As a concept of synergetics, coherence (from Latin ‘to hold together as a unit, to connect’) has widened its meaning: it denotes consistent and orderly agreement of behavioural patterns of the system components during self-organisation. Coherent dynamics of the elements and parts of a complex system are a basis for the emergence of complex spatial-temporal structures out of chaos [see: 32: 237–238].

Coherence is a property of a system (not of an element) and one of the conditions of the system’s functioning and development.

On an Interdisciplinary Character of Synergetics

A disciplinary approach to the study of an object implies the usage of notions and categories, as well as a methodology of analysis, elaborated within a particular discipline.

An interdisciplinary approach is realised in at least two directions. Firstly, it presupposes expansion of the set of categories and methods of analysis at the expense of those from other disciplines. Let us call it a centrifugal vector of interdisciplinarity (see Fig.1.5).

Secondly, an interdisciplinary approach is a cooperative study of an object when it is placed into the sphere of scientific reflection of researchers working in different fields of science and/or belonging to different academic schools of thought. It is a synthesis of methods and concepts of two or more disciplines. Let’s call it a centripetal vector of interdisciplinarity (see Fig.1.6).

The interdisciplinary methodology is a horizontal, associative network of links, integrating experience, modes of thinking and methods of particular scientific fields. The disciplinary methodology is vertically structured, digging into the depths of the object of investigation, and more or less limited by the boundaries of its own discipline.