Dietrich Fliedner

Processes Constitute our Complex Reality
A Theoretical Investigation

Saarbrücken, Oktober 2001

Foreword

Complexity and emergence, systems and processes form a set of notions which represents a particularly promising area of modern interdisciplinary research. Whether we are concerned with the reactions of molecules in chemical substances, the movement of flowing gases and liquids, the co-existence of living organisms in biotic populations and ecological ensembles, or the behaviour and actions of human beings in social groups, in each of these cases, the interplay of individual elements is examined within the context of the whole.

This paradigm originates in the 1920s and 1930s. In the field of physics, it had become generally accepted that the traditional deterministic-causal view of things was no longer sufficient as an explanation for reality. The theory of probabilities became widely accepted (from a philosophical point of view: POPPER 1934/89). It already announces the concept of whole and components.

In the social sciences, a corresponding development took place, but with a certain delay. In the 1950s, within the context of empirical social research, reliance was placed initially on statistical methods based primarily on the theory of probabilities. Here too, the deterministic view was no longer adequate, since social scientists deal with humans whose actions follow their own intentions (and emotions).

Probabilistic models were also developed in the field of anthropogeography (GARRISON 1959/60). In this field, simulation also began to be used increasingly, e.g. in the study of migrations and the diffusion of innovations (HÄGERSTRAND 1952; 1953/67). In Germany, following the dark years of National Socialism, social geography became established as an independent sub-discipline - a development which had begun earlier in other European countries. The social group in space now became the central object of research (BOBEK 1948; HARTKE 1953; HAHN 1957).

However, system research was already in use in the 1950s, especially in the field of biology. Within a system, the components co-operate with one another in such a way that they stimulate and subdue (i.e. regulate) one another mutually. The foundation of the theory of information (SHANNON and WEAVER 1949/76) and the development of the theory of self-regulating systems (WIENER 1948/68; v.BERTALANFFY 1950) created a formal basis. In this way, closer attention was given to the progress of time.

Lateron, system research also made its appearance in the economic and social sciences, again after a certain delay in relation to the natural sciences. FORRESTER (1968/72) developed a model with the assistance of which the interplay of different components (e.g. number of inhabitants, housing construction, industrial production, social product etc. in a town) could be simulated.

In the field of geography, the question was discussed as to how landscapes - seen as physical-anthropogeographic units - could be understood as systems (SOCHAVA 1972; SCHMITHÜSEN 1976). However, in social geography, it then became accepted that physical geography was dealing with quite different objects than anthropogeography and that these sub-areas therefore had to be separated (BARTELS 1968). The intention was to focus much more interest on human beings. In the following years, humane-scientific hermeneutic-phenomenological methods of explanation became increasingly popular (HARD 1970), while attempts to formulate processes and phenomena mathematically were classified as scientistic. They were relegated to the background, a tendency which increased during the 1980s and 90s.

Through the influence of post-modernist ideas (e.g. J.POHL 1998), social geography approached the social sciences more closely. The theory of action was strongly influenced by this tendency and received a guiding role (WERLEN 1988; 1995-97). The mainstream of social geography now received a more humane-scientific bias (which it still possesses).

The development in the natural sciences took a quite different course. As early as the 1970s, research into non-linear systems, including the emergence of chaos research was established. Again new methods of explanation were demanded, and simulation became the most important investigative instrument. The use of computers made a decisive contribution to this.

It was recognised that systems, although subject to deterministic laws, do not behave predictably. In their simulated development, they may be driven to the edge of chaos, thus causing new patterns to come into being. Against this background, it became apparent that spatial patterns can also develop, so to speak, "from the bottom up" (PRIGOGINE 1979; MANDELBROT 1977/87; HAKEN 1977/83).

During the 1980s and 90s, parts of the natural sciences and social sciences were moving towards one another on a more abstract level. Chaos research developed into complexity research. With considerably more ambitious objectives than chaos research, it opened up the prospect of unfolding not only more complicated spatial patterns, but life itself and human society, in other words highly complex structures. It was recognised that self-organising systems occupy a key position in our understanding of complex structures such as the living world or human society. Using the method of "cellular automata", attempts are being made to simulate "artificial life" (LANGTON 1989) and "artificial society" (EPSTEIN & AXTELL 1996).

Looking back, we note that time, i.e. change, "becoming" was becoming a factor of increasing importance in the general approach (PRIGOGINE 1979). The more precise step by step analysis of objects and the increasing understanding of the inter-relationship between whole and elements made it possible to move the process to the centre of attention, i.e. to focus more closely on time and its significance.

But now problems arise, on the one hand in the theory of complexity. Neither in the simulation of "artificial life" nor in that of "artificial society" has it been possible to make decisive progress in explaining self-organisation, i.e. differentiated, permanent systems based on division of labour, e.g. self-organising populations (see section 2.4). This may not be necessary for dealing with many questions, but when animal populations or even human society, with their flows of information and energy, are being simulated, there is no alternative but to research the populations as well. Even emergence research (KROHN & KÜPPERS, publ., 1992) which is devoted particularly to the appearance of complex structures, has still not come up with a satisfactory explanation for the phenomenon of self-organisation. Perhaps complexity research has overestimated the capabilities of the computer.

On the other hand, social geography, with its humane-scientific bias, is faced with new problems. On surveying the development of anthropogeography over the last decades, it can be seen that we have moved forward with increasingly accurate methods from the undifferentiated human groupings via the "social groups", "institutions", "behaviour" and individual "roles" to individual "actions". Now that we have arrived at the microlevel, we cannot find our way back to the macrolevel of wholes and processes. So, here too, it has not been possible to distinguish plausible constant and limited human populations with structures intrinsically based on a division of labour. Apparently, many social geographers still believe they can arrive at a definition of social reality without the assistance of the knowledge possessed by the natural sciences. Thus, empirical research remains confined to disciplines concerned with human society in its many forms, but without a satisfactory theoretical basis.

With this in mind, the intention of this treatise is therefore to indicate a feasible path to be taken by both complexity research and social geography. The process occupies a position of primary importance. The considerations are based mainly on the empirical and theoretical studies undertaken by the author in the field of historical and social geography over the past four decades. The most important results of these studies will be summarised here. Readers requiring more detailed information (and references) are referred to previously published work by the author (particular 1981, 1993, 1997 and 1999). In its conception, the discussion will follow that of the book published in 1999, but the text is completely new. It will further develop the ideas and place them in a higher context. Here too we will progress systematically from the simple to the complex because that appears to be the most logical approach from a didactic point of view.

I am indebted to many people who have assisted me in compiling my manuscript, among others, to Mr. Thomas Fläschner for information on recent literature and to Mr. Neil A. Waugh (Meschede) for the English translation.

Content

1. Introduction

Actually it would seem more logical to carry out such studies of complex structures (see foreword) on a scale corresponding to our own experience ("Mesokosmos"; VOLLMER 1985/86, pp. 57), in an environment in which we ourselves act and are acted upon. We know where we stand (from a systematic point of view), what we want, to whom we are answerable and what we achieve. The object of research with which anthropogeography is concerned, human society in the ecumene, offers especially illustrative examples of complex structures. Consequently, the geographer should feel encouraged to give more attention to this subject from a theoretical point of view. However, to date, very little interest is apparent, in spite of the fact that geography itself would benefit, since such work would contribute to our understanding of the multitude of facts with which it has to deal. Furthermore, it could contribute new ideas and impulses to related disciplines such as sociology and historical as well as to the natural sciences.

For our purpose, it would seem most obvious to commence with the system concept, since, on a general abstract level, it facilitates our understanding of the interplay of different components and the formation of wholes. However, complexity can be formalised not only with regard to the structure of links and space. The concept of simulation of processes should also be used, because in this, temporal aspects come to the fore.

In our concept, special importance is given to the course of time i.e. processes. Up until now, they have received too little attention. In their succession, the processes can join up dissimilar things to form a temporal whole. Every process has a beginning, undergoes acceleration, slows down and finally comes to an end. This also has qualitative consequences. As an example, we may take the adoption of an innovation. In the economic sciences as in geography, particular emphasis was given to the aspect of diffusion of the innovation in time and space (see section 2.3.4.2). For example, the cultivation of a certain type of maize spreads over an area characterised by agricultural activity through recommendation within the framework of neighbourhood contacts. Thus, the number of farms adopting the innovation increases. At the same time, the temporal sequence of the process within an adopter, i.e. a farm, should also be taken into account (ROGERS 1962/83). The adoption of a new type of maize prompts a revision of the financial planning within that farm, re-planning of the work to be done in the course of the year, the procurement of new seed, the purchase of new machinery, the creation of storage facilities etc. This qualitative diversification in the succession has to be formalised. In this way, complexity becomes an object of examination with several dimensions, whose research demands a different theoretical approach as has been taken up until the present (e.g. in "artificial society"). We describe this new approach as the "process theory".

The first impulses go back to the 1960s. For example, in his study of the foundation of small ports ("Sielhäfen") on the North Sea coast of Central Europe, SCHULTZE (1962) found a sequence in the development of this type of settlement which passed from irregular early forms to perfectly regular forms following a certain scheme, and then back to poorer irregular forms. Similarly, in my examination of settlement areas to the north of Bremen (1969), I noted that the shaping of the cultural landscape, the formation of the traffic network, the growth of the cities, etc. in the Middle Ages and in modern times had gone through the same type of development. Another problem was created by the discovery of latent rotation effects in several population and traffic movements in various West German cities (1962). All this seemed to indicate that processes take place according to certain rules, which at that time I was still unable to specify.

In the further course of my inductive historical and social-geographical work, I put forward a first version of the process theory (1981, 1990). It recognises process sequences and non-equilibrium systems as the most important structures, i.e. self-organising wholes in time and space, structured according to division of labour.

From the start, the aim was to arrive at results which revealed fundamental natural and economic structures in human society and whose findings possessed a level of logical objectivity which was also acceptable to the natural scientists. Human beings consist not only of mind, a fact which is not given enough consideration by the protagonists of a hermeneutical-phenomenological social science. On the contrary, a considerable part of his actions are determined by physically based necessities (e.g. eating and drinking, energy-saving effective behaviour, sleep). This aspect of human existence leads to the general problem of the effective use of energy. Thus we arrive at another level of cognition where laws apply to which humans as well as biotic and inorganic phenomena must submit. This entitles us to give some thought to more general explanations of certain phenomena in nature beyond the social reality. The flow of information and energy, the structure of processes and systems, qualitative thematic differences in matter, space, time and hierarchies, form characteristics which are valid for all areas of existence.

To date, the strongest impulse for research into complexity has come from the natural sciences (see foreword), and the social sciences (in the wider sense) adopted some of the methods and results, naturally in a modified form. The question now arises as to whether the discussion could not receive impulses from the social sciences which would be of interest to the natural sciences. The social processes in question allow us an insight into the phenomena of our order of magnitude. In particular, the qualitative differences can be examined for their meaning and historical sequences interpreted. These are possibilities which the objects of study of the natural sciences only offer to a very limited extent, if at all. However, caution is required:

In the exact sciences for example, atoms or galaxies are observed as objects and their formation studied. For the biologist, the question of meaning, e.g. of certain organs for the organism, is of importance, especially if he wishes to reveal the systemic structures. Similar principles also apply for the social scientist. Thus, in the context of the process theory, such questions as the thematic position of individuals within the whole are unavoidable. Events and processes have a specific meaning for the structure of populations and processes. These have to be identified and plausibly interpreted.

At the start, there is the attempt to understand the object under study, i.e. what has occurred and been formed in the past. We are dealing with human beings who have formed the process of history, through their actions. Trying to determine their motives in detail would be a hopeless task. However, their actions are subject to a number of different preferences and constraints, and these indicate the path to be taken by the analysis, because they arise frequently in the context of superior processes and populations. Individuals are embedded in these, they belong to systems which expect certain behaviour from them which are essential to their self-preservation and self-organisation. In other words, seen in a systemic context, actions and processes have specific tasks for the whole. The purpose of an analysis is to identify these tasks and categorise them.

This applies for events which took place in the past and whose results we know. We thus avoid the difficult question as to the motives and purposes of the actions and processes which, even at that time, pointed into the future. In the examination of present structures this is different. For example, we cannot identify in advance the technical innovations which will be adopted in five years' time. With systems geared towards a purpose, e.g. individuals and populations (see section 2.4), we can however predict the quantitative course of developments which have already begun (e.g. economic cycles) with some degree of accuracy. We can also say that such processes will normally end in a result which is predictable with a certain probability (unless affected by outside intervention), but only within a typological framework and at structural level. Thus we can perhaps predict the approximate form which will be achieved by a living organism or a population if we are aware of the structural data ("equifinality"; see DRIESCH 1908/28, p. 133 f.; v.BERTALANFFY 1950, p. 25). The individuality of the process and therefore the quality of the results are however unknown.

Thus, it is correct to speak not of teleology but of teleonomy (PITTENDRIGH 1958, after WIESER 1998, p. 331). In a teleological process, an individual or a smaller organisation knows a definite aim which it has set itself, whereas in teleonomic processes the individual aim is not normally known, although the general aim is fixed structurally in the program.

Now the most important conditions of the framework within which the discussion will proceed, have been described, at least in outline form. The aim of the argument is to obtain an intrinsically logical concept at an abstract level. The statements made must support one another mutually. Taken on their own, some interpretations may not appear plausible. They must be seen within their context. If everything fits together, the structure will be self-explanatory.

In the main chapter (2) following this introduction, the material will be assembled. We will attempt to define the various possibilities of coexistence between the components of systems according to the various degrees of complexity. In doing this, we will establish the archetypes of the processes and systems in order to arrive at an intrinsically consistent and complete typology. In the concluding chapter (3) we will attempt to provide an explanation, naturally at a very general level only.

2. The levels of complexity

In the individual case, when inductively examining a certain system, it is necessary to take the direct approach to resolving its complex structure. In this treatise however, we will attempt to review the multitude of complex structures and to form an explanatory theoretical model. The most obvious approach is to proceed from the less to the more complex. Thus, levels of complexity can be identified which are characterised by certain types of processes and systems. In addition, in each chapter devoted to a level of complexity, an inductive approach will be adopted, i.e. progressing from the individual to the general, and from the concrete to the abstract:

1) As an example, we will take an industrial company, a small weaving mill which continued working into the 1970s.

2) The observations will then be transposed to a more general level.

3) A model will then be developed from this.

4) Finally, other examples will be used to demonstrate that the model can be generally applied within the given framework.

2.1. Simple movements and solida

2.1.1. The textile factory

In a Westphalian town, a small weaving mill which manufactured damask materials and cotton blankets, continued in operation into the 1970s. It stood apart from important railway lines and roads in a mixed residential and industrial area and covered 3/4 of a hectare. The single and double-storeyed red-brick buildings were grouped around a small yard with a flower bed in the centre, thus forming an enclosed unit with a large factory building containing the looms, a boiler house with a brick chimney, offices, workshops, store-rooms, a garage for vehicles etc. (see fig. 1). The factory had around 200 employees, most of whom lived in the neighbourhood. The company itself was founded by a Wesphalian businessman and his partner at the end of the 19th century. It was forced to close during the slump in the textile industry in the 1970s.

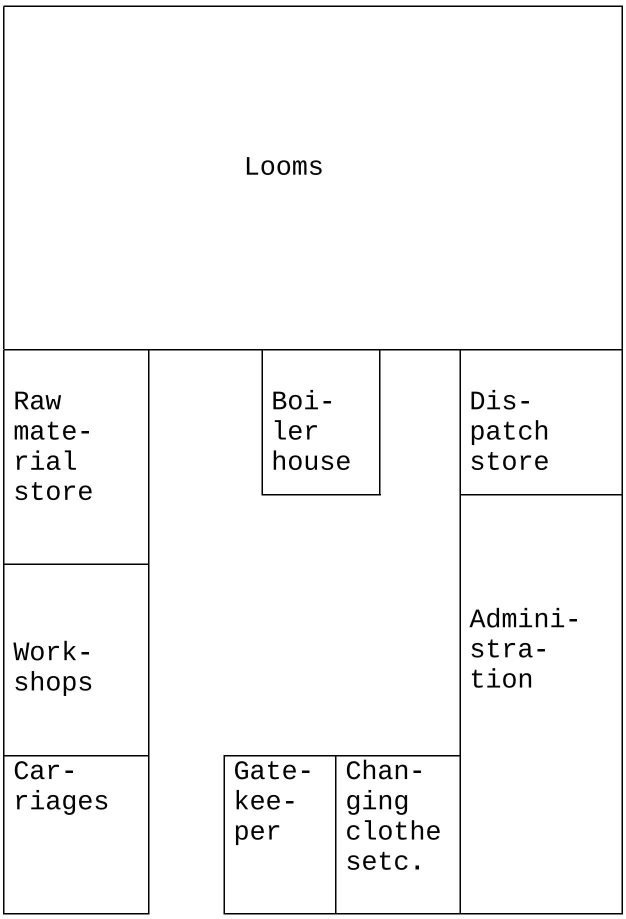


Fig. 1: The textile factory

2.1.2. General considerations

We may explain the factory causally (BUNGE 1959/87). From the result (the existence of the factory in its shape) the existence of the "forces" (who themselves have causes) is inferred. The forces which led to the setting up of the factory: the Westphalian businessman and his partner who built up the company in accordance with the state of production technology at the time, the construction workers, the manufacturers and suppliers of the machinery, the shop-floor and office workers who kept the factory running etc. The causes: a strong rise in demand for textile products during the 19th century which was itself caused by an increase in the population, the growing wealth of the population which permitted the purchase of the factory's products, the liberalisation of world trade which facilitated the import of cotton, etc.

Around the turn for the 20th century, the study of geography was concerned with the scientific investigation of tangible space with its "forms" (SCHLÜTER 1905; HETTNER 1927), and the factory was such a form. The method is very imprecise and poses new questions which are only dealt with at a later phase in the history of the subject (see section 2.2, 2.3). Above all, with this type of explanation, the stages between the emergence and the time of the investigation are of no interest. Thus, there is no means of interpreting the development of the company as a process. The causal method is only accurate enough if one can assume that between the time of the cause and the time of the effect there is no differentiating process of change between a first and a second state.

Thus, today it is not possible for us to make inferences regarding the causes of the creation of the factory from its present state, and certainly not within the context of our attempt to deal with the process theory. It is more likely to be possible to bridge the difference between the two states of the factory site before and after the construction of the factory. The first state was transformed into the second state by means of forces. This means that the second state is the result of forces which go back to causes at the time of the first state. However, the hiatus between this second state and the state of the factory around 1970 (before its closure) cannot be bridged by means of a causal explanation, because if one did this, one would have to assume that in the meantime no changes had been effected (which does not reflect the reality of the situation).

The site of the factory before its construction and the factory after construction are tangible forms which we will call "solida". At this level of complexity they are not subdivided in themselves and for this reason are not systems.

Strictly speaking, the individuals transform the forms from the first into the second state by means of their actions. Thus, the fundamental "process" which we wish to study more closely here, is the action. Much has been written about actions and from the point of view of many different disciplines (LENK 1977-82; POSER ed. 1982; WERLEN 1988, 1995-97). But what interests us here is as follows:

Actions constitute and shape the individual environment, they lead from one state to another. There is a "before" and an "after", an action is begun, executed and ended. Something immaterial (information) or material is created, or something is altered which had been created (by someone or other) beforehand. Two types of action can be distinguished: action motion and action project.

"Action motions" are simple movements, they take seconds or fractions of seconds. They can carried out consciously and goal oriented by the individual. However, they also include affective actions guided by instinct or unconscious reactive actions or movements. Action motions are the smallest units which cannot be differentiated further in this respect.

The "action project" on the other hand is a planned piece of work to achieve a specific purpose (e.g. the ploughing of a field, the writing of a book etc.). Action projects demand longer periods of time (see section 2.2). Here, in this chapter, we will deal more closely with the action motions. With these, in contrast to the action projects time is not regarded with any differentiation. The action motions are of interest only to the extent that they are open to causal explanation. They have a cause and create effects.

Action motions must physically affect the environment in some way. They do not necessarily have to be executed by hands. Speaking and stepping are also action motions in the sense of our word. However, reflections, or concentration of the senses on something in the environment are not yet an action motion, although they may well prompt an action motion. An action motion serves to fulfil an instantaneous purpose and is bound up with one person, the "agent" from beginning to end. Thus it is a (possibly preconceived) movement carried out by a person, which, by using force (energy) achieves an effect, and moves something else e.g. a stone, in the environment.

Through a multitude of action motions, the natural spatial environment and the "earthbound artefacts" created by human beings are altered in form and energy content and transformed into a new state. The factory is one of these earthbound artefacts i.e. buildings, earthworks etc. created by man for specific purpose (e.g. houses, roads, fields). They give the cultivated landscape its appearance. Man forms nature, shapes and modifies the landscape for his own purposes. He alters existing characteristics and transforms it from one state to another. He may well use machines or tools ("media") in the process. We call such earthbound artefacts and the media "solida". They receive and transmit energy.

The alterations concern the shape, size or quality and quantity of the objects without these having to lose their identity. To alter means to make or become different. As a rule, this takes place on the spot. The alteration of an object can be regarded as a movement on the micro-level. Alteration in location on the other hand involves the movement of a person or an object from point A to point B. As stated above, actions are movements carried out by persons. The term movement is therefore more comprehensive in its meaning. Thus, we have roughly defined the basic unit from which emergence and complexity can be derived.

According to the process theory, it is important that the solida absorb energy and release it again through the movements within the context of motion or change. To this extent, a bridge to the systems exists structurally.

In the scale of complexity, movement and solidum are located at the beginning, and although neither a complex process nor a complex system is involved, we will refer to it as the 1st level of complexity for the sake of uniformity of scale.

2.1.3. The model

The movement of a solidum represents the physical implementation of cause-effect connection. The reason (antecedens) is the logical condition for the result (consequens). Such relationships of conditions are an expression of regularity, not as a succession of stages in a process, but as a framework of deterministic laws. They are of structural theoretical importance (compare with the flow processes, section 2.3.3).

Here, Newton's third law of motion should be considered: "The effect is always equal to the counter effect or the effects of two bodies on one another are always equal and opposite in direction" (NEWTON 1681/1725/1963, p. 32). Actio => Reactio. In other words, the energy of motion lost by one body is gained by the other (R.W.POHL 1947, p. 21).

Let us take the simplest form of energy transmission: the movement of a uniform reacting object, a solidum. E.g. if a stone receives an impulse from outside, from a body in the environment: The energy is received by the solidum (stone) and converted into kinetic energy. The solidum moves in a certain direction, it is accelerated. The energy is passed on, transmitted to the environment in the form of frictional energy which is transmitted to the ground beneath and/or by another body being struck and taking over the kinetic energy. It is the most simple form of energy flow.

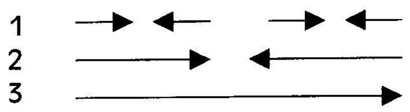


Fig. 2: Symmetrical structure within the context of energy transfer.
Input - acceptance - redirection - output
Inwards - outwards
Basic orientation of the impulses

Let us now try to explain what exactly happens in the solidum (see fig. 2):
- The impulse from the environment is put into the solidum which has a certain inert mass and potential energy: "input".
- The solidum cannot move immediately, it must first absorb or accept the energy. We are therefore considering the process from the point of view of the solidum: "acceptance".
- The internal stress now occurring in the solidum is converted into kinetic energy, i.e. the energy receives a new direction: "redirection".
- The kinetic energy is now passed on to the environment, e.g. through friction: "output".

The first two parts in the sequence lead into the solidum ($\vec{p}$), and the following 2 parts out of it ($-\vec{p}$). Moreover, we distinguish the input into the solidum (1st part, $\vec{q}_1$) and the acceptance of this impact by the solidum (2nd part, $-\vec{q}_1$), as well as the redirection i.e. the change into kinetic energy (3rd part, $\vec{q}_2$) and the output of the kinetic energy to the environment (4th part, $-\vec{q}_2$).

We will encounter this double symmetry in the context of energy transmission (which itself is asymmetric) again and again, even in the systems at higher levels of complexity.

The environment affects the solid, the solidum reacts as a passive quantity and is completely controlled by the environment. The environment in its turn is altered by the solidum when it is moved. In the last resort, this is due to the influence of the environment. The environment is responsible for the behaviour of the solidum.

The movements can be described using the well-known equations of motion in mechanics. Mass (of the solidum) is accelerated and for this purpose, force is required. The formula is as follows (where $\vec{p}$= force, *M* = the mass of the body, $\vec{v}$ = speed and *t* = time):

[1] $$\vec{p} = M * \vec{v}/t \quad ,$$

i.e. the mass *M* of the body is accelerated, the impulse comes from outside, from the environment. The accelerating force converts the potential energy in the mass into kinetic energy.

Energy is defined as the ability to do work. It can be derived directly from the work. Work is defined as the relationship force*distance $\vec{p} * s$.

The kinetic energy is calculated using the formula

[2] $$\vec{p} * s = \frac{1}{2} M * v^2$$

(M = mass of the body, *v* = speed, *s* = distance).

In the movement of the solid body (solidum) described by this formula a number of dimensions are apparent:
1) First, there is the energy which is contained in the mass *M* of the solidum, or which is expressed in the accelerating force.
2) Then there is time, which is expressed in the speed *v*.
3) Another dimension is indicated in the condition relationship antecedens-consequens, namely the hierarchy. The impulse represents an order which has to be obeyed, thus producing movement.
4) Distance is a property of space. In addition, the solidum defines space through itself, i.e. its substance fills up space. The limits of the solidum also designate the limits of space. Space and form become identical at this stage of complexity (see section 2.6.3.3).

In the course of the discussion, we will see that with each step from one level of complexity to the next, one of these dimensions is exposed (see also section 3.2.4).

2.1.4. Other examples

The question why a thing is as it is, is the first step on the way to knowledge. This question can (hypothetically) be asked for each definable tangible form, and one will frequently be able to infer the cause from the recognisable object. For the geographer, the surface forms of the earth are such objects, which are studied in the sub-discipline of geomorphology. Mountains, plateaux, terraces, slopes, valleys, plains are shaped by endogenous and exogenous forces, i.e. they are "forms". Geomorphologists regard it as their task to describe these and to study the "forces" which have shaped them as well as their causes. Causal explanation dominated the concepts and approaches in geomorphology well into the second half of the 20th century.

"Forms" therefore appear as solida. In principle, every substantial thing which can be moved and altered may be regarded as a solid. This includes everything tangible, for example the cultivated landscape with its universe of forms. All earthbound artefacts at every level and on every scale such urban and rural settlements, roads, bridges, fields, mining and industrial areas are some examples. These forms can be described, compared with one another, classified and cartographically documented. And for many years (into the 1920s and 30s), geographers also tried to explain them causally. They are solida, whose creation was controlled externally. However, who controlled it, when did it happen and what took place in detail? We have already seen (see section 2.1.2) that it is not possible to examine these objects using exact methods, in the same way as a physicist. The more complicated the form, the more varied their history, the more vague the results of causal explanations.

However, if we look more closely, we would say today, in the sense of our process theory, that these forms were created by action motions or movements which in their turn can be explained causally. The solida which are perceptible in our order of magnitude represent an archive. Every action motion, every movement has left its traces which can be investigated hypothetically and explained causally. Naturally, the results do not explain much. They do not explain the peculiar nature of these solida or their specific shape. Here, analysis of the complex process sequences is the only way forward.

2.2. Movement projects and equlibrium systems

2.2.1. The textile factory

As described above, the collection of buildings making up the weaving mill was arranged around a central yard. A paved road passed along the front of the buildings, linking them with one another. In the buildings themselves, the employees worked in their various functions. From the road, the entry to the factory led past the gatekeeper's lodge, which adjoined a multi-purpose room for the use of the workers (see fig. 1). Here they were able to change their clothes, spend the intervals in work etc.

The right-hand front of the central yard was occupied by the two-storey administration building, with management, marketing, purchasing, planning, design offices etc. The building on the left of the entry housed the garages for vehicles and the workshops. In the rear part on the left, the raw-material store was located and at the rear on the right, adjoining the adminstration section, the dispatch store. Both of these were equipped with loading ramps.

At the rear centre, the boiler house was situated, with a steam engine and a coal bunker. On the left and right, paths led past the actual production shop containing the looms. Originally, the machines were connected with the steam engine by transmission belts via a common drive unit. After the Second World War, the old looms and the steam engine were taken out of service and were replaced by modern looms driven by electric motors.

The various buildings were easily accessible from the central square and arranged in such a way that the distances to be covered for the production process were as short as possible, but also that the production workshop with its noise did not directly adjoin the administration building and the free area.

This division into various buildings and rooms permitted the functional division of the company into working units. The arrangement and size of these units were planned in such a way that the company was able to function efficiently and prosper as a production unit. And the company as a whole was also able to maintain an energetic balance between supply and demand. In other words, it functioned. In these units each employee had his own well-defined task to perform. He had his working space and worked according to his capabilities. The wages provided the workers with a modest but adequate living. The workload on the one hand was balanced by the possibilities for consumption and recuperation on the other. The factory was organised on partriarchal principles but no exploitation of the employees took place. In terms of energy, the individual was constantly in a state of balance between energy supply and energy consumption.

This striving for equilibrium is also apparent in outward relations. The raw material, especially cotton yarn of various qualities was generally delivered to the factory from various spinning mills in neighbouring towns. The raw material was transported to the factory by rail and the finished fabrics taken away by the same means. Within the town, they were transported by horse and cart as this was the most economical method.

Most of the workers lived close to their place of work. From most of their houses, the factory was easily reached on foot or by bicycle. As yet, no car park was required. The catchment area for the workers was therefore small, only very few of them living in outlying communities. Greater distances would have meant greater expenditure of (costs and) energy.

2.2.2. General considerations

Each of the various departments of the company had a number of employees co-operating with one another in the same functions, for example those employed at the loom, in the stores, in the marketing department etc. Thus, the employees can be assigned to certain characteristic groups depending on their activities or functions.

Since about the 1920s, geographers have been studying the multifarious aspects of the economic and settlement structure in a given area, dividing the object observed according to functional criteria (see section 2.2.4.2), as shown here using the example of the textile factory. In this way, more attention came to be focussed on the human being himself. It was recognised that man pursued his intentions on the one hand, but that he is subject to certain laws on the other, which have the result of restricting the possibilities open to him. This conflict finds its expression in the spatial sub-division of the cultural landscape as well as in the economy.

When investigating the arrangement of such structures, it is obvious that causal explanations have very little sense. To arrive at an explanation, we must first study the individual actions and agents. It is important firstly to consider the individuals as members of social groups and the groups themselves as characteristic groups within their environment, i.e. that the details become understandable by their integration in the whole, and the whole by the arrangement of the details.

This approach is reminiscent of the hermeneutic method which has dominated interpretation in the humane disciplines since the 19th century. It was attempted to understand actions and historical processes against the background of the environment or the situation. The detail is regarded separately from the whole. The whole is known or at least explicable with the result that the detail fits into place. The object requiring explanation (explanandum) is placed in its functional context, i.e. in the context relating to sense. In order to recognise its sense, all the knowledge available on the object being explained must be placed in a coherent, logical and accurate context.

If one uses the context of sense for the purpose of explanation, this also means that one assumes that human actions have a sense and that they are functionally understandable. The actions concerned here are, for the most part, "action projects" (see section 2.1.2) which are carried out principally with intent. The meaning context is at the same time an effect context (GADAMER 1960/90, II, S. 31), a real context with the result that we have a mental transition to the economic and natural-scientific view of things.

The projects are devoted to a task, e.g. the transport of goods from the factory to the station, the preparation of a meal, the operation of an electrical appliance, the writing of a book etc. Such projects consist of many action motions and can be carried out in different ways. They may take hours, days or years. Each individual is faced with the problem of carrying out his work, i.e. his action project, as efficiently as possible. The efficiency of human action depends on the possibilities open to the person in question. Not only the work itself, but also overcoming distance demand time and energy, i.e. the effort involved in the transport process must be added to the effort necessary to execute the actual work.

In the textile factory, this was taken into account in the arrangement of the departments, administration, stores, production etc. Within these departments, the individuals worked with the same aim in view, they had to cover the distances to the department coming after theirs in the production process. Consequently, the departments were arranged in such a way that they could co-operate with one another as effectively as possible, i.e. if possible without any waste of time. Greater distances mean more time required to cover them and greater expenditure of energy, i.e. higher costs, which would have placed the company at a disadvantage.

As with the action motion, the individual is also responsible for the action project. He defines the action projects aimed towards a certain purpose, or which have a certain function and into which many action motions are integrated. The action motions are what consume the energy. During the execution of the action project, the energy is withdrawn successively from the organism, which was previously supplied with energy independently of the work, as permitted by the resources. Contrary to the action motion, energy consumption and time consumption are separate. Thus, the individual is not seen as an undifferentiated solidum, but as a system which can store energy, which consists of sub-systems and elements (organs, cells, which do not have to be more closely specified here). Put another way, in the system, time and space are removed from the entirety of the energy transmission process, which in the case of the solidum is still a unit (see section 2.1.2). In this way, they can be made more flexible and individually formed in accordance with circumstances. Thus, we are dealing not only with a relationship of conditions (as with the action motions), but a process.

In detail, we can state that in this process, 4 stages have to be passed through:
1. The individual, (from a general point of view, the system), receives the order from the superior and preceding environment, i.e. from the company management, to carry out the action project "transport of goods to station".
2. The individual (the system) accepts the order and demands the energy required from himself, which was absorbed beforehand as nourishment or other form from the energy-supplying environment.
3. The individual (system) prepares the execution of the command (planning of the tour, loading of cart etc.).
4. The individual (system) delivers the freight (receipt of goods at the station).

The action project of the individual is only an example. In a more general way, we may speak of a movement project. Each movement project can be sub-divided into many small individual projects, all of which proceed in basically the same way:

input (of stimulus and/or energy impulse),
acceptance (in accordance with individual possibilities),
redirection (to intended end, preparation for work),
output (execution of work, delivery at destination).

That in reality, every movement project is repeatedly disturbed and interrupted by subordinate movement projects is obvious, but changes nothing in the fundamental rule. If necessary, intervals may occur during this process according to individual requirement. The personnel may be changed or replaced. Thus, the individuals maintain an energetic equilibrium between the energy available to them and the work to be carried out. The individual is the carrier of an "equilibrium system".

The textile factory is also an equilibrium system from a structural point of view. It is composed of many individuals who carry out their motion (action) projects as elements in the interests of the company.

2.2.3. The model

Here, we should first consider the sequence of the movement project from an energetic point of view. The movement projects are not processes which are distinguished by thematically differing stages fixed in their temporal rhythm (c.f. conversion process, section 2.4.3.2). Rather it is only the succession which is ordered structurally here.

The process of transmitting an impulse from the preceding environment to a system composed of elements, as shown above, takes place in four stages. The same rules apply for the transmission of energy (e.g. in an impact) as for the transmission of a demand for energy (i.e. an information). Both stimulate a process. For our process, it is therefore immaterial whether we enquire about the energy or the information content of the stimulus (negentropy). The most important thing is that the input (from the preceding environment) and the output (to the succeeding environment) assume values which can be increased or reduced linearly. The processes can be represented by formulae which describe the sequence with regard to its development in time and space.

Stage 1 (input):

The question is: how much energy (or information) can be put into the system? The search is for a value capable of being added before and after the input. It should be taken into account that the elements are the energy carriers and that only so much energy can be input as can be exchanged between the elements. The possibilities for combination between the elements therefore have to be taken into consideration.

The quantity of energy (or information) which can be input depends on the degree of order in the system. If this value is high, the system is very differentiated or very ordered.
The energy is exchanged in equally large portions (quanta) between the elements. Let us assume that system contains 2 kinds of elements (e.g. a and b) each of which occurs in groups of 10 (e.g. sequences of the letters a and b). There are then 2^{10} possibile combinations, i.e. micro-states. If the size of the group is doubled (i.e. increased to 20), we obtain $2^{10} * 2^{10} = 2^{20}$ micro-states. That is, the number of micro-states has to be squared. But the information content (negentropy) also has to be doubled in accordance with the size of the

group, if we comply with the condition that the values can be added before and after the input. This means that the ratio is correctly reflected by the logarithm. In other words, the quantity of energy (or information) which can be input is characterised by the logarithm of the number of micro-states. In the theory of information (SHANNON & WEAVER 1949/76; SCHWARZ 1981) the logarithm is selected at basis 2 and the negentropy receives the dimension bits.

The energy (or the information) content may be represented by the simple formula

$$I = \log_2 r = ld\ r ,$$

where r is the number of micro-states and I the energy (or information) content. It should be noted that each of the r micro-states appears with the probability $p_i = \frac{1}{r}$, so the formula for the energy content is

[3] $$I = -ld\, p_i = ld \frac{1}{p_i}\ bits$$

Stage 2 (acceptance):

This absolute value which applies to the system as a whole, must now be transferred to the number of elements.

How much energy (or information) content the elements (as the potential adopters) can still accept is determined by a rational function. The required relative value d represents the proportion of the elements who can still be loaded, and the value w, the fraction of the elements who could definitely absorb the energy. If w = 1, each element can accept the energy (or information). Then, d = 1 too, i.e. the system is fully loadable (i.e. able to accept energy or information). If w = 2, d = 1/2, i.e. there are only half as many elements. This produces the formula

[4] $$d = \frac{1}{w}$$

Stage 3 (redirection):

Now the energy (or information) is diffused into the bulk of the elements. The diffusion is based on the simple positive exponential equation (discrete form):

[5] $$N_n = k * N_{n-1} \quad \textit{adopters}$$

where k is a constant, N the number of adopters, n the number of time steps.

Stage 4 (output):

In the last stage the relation between the adopters of the system and the potential receivers in the succeeding environment is determined. Let us assume that the event that an element contacts a potential receiver equals E. In a sequence of x_n tests the event E occurs x_m times. X is the random variable. So the equation is

[6] $$f(x) = P(X = x) = \frac{x_m}{x_n}$$

Let us now assume that there are many movement projects, in which traffic movements, i.e. travel over certain distances, predominate. Thus we come to the spatial aspect of the process (see fig. 3). If many such movement projects are aligned towards one centre (see fig. 3a), that can be understood as the addition of movement projects in space. Here, we are concerned only with the relationships, not the movements themselves, but with the "long-range effect" as such. The carriers of these projects move back and forward between a point A at the centre and a point B in the "umland" (surrounding country). More and more space is available radially from the centre towards the periphery (similar to the Law of Gravity). Thus, the density of these movements is very high in the vicinity of the centre and declines towards the outside, very rapidly at first and then more and more slowly (see section 2.4.3.1).

If, instead of a point at a centre, we assume a line with many points A, and instead of surrounding country, we take a "foreland" with many points B, the long-range effect of A to B can be described as a linear relation (see fig. 3b).

2.2.4. Other examples

2.2.4.1. Examples on a local scale

Farms have always had to rely particularly on the various activities being functionally separated. A good example is the traditional lower German standard-type farmhouse ("Niedersachsenhaus"). The larger front part is devoted to the work of the farm. Through a large door in the gable wall, access is gained to a large vestibule ("Diele") where the various jobs in the building or in the field were coordinated.

The large attic was for storing hay or straw. On both sides of the vestibule were the stalls for cattle, pigs and horses and above these the rooms for storage of threshed grain, animal feed, tools, etc. The sleeping quarters for the labourers were often to be found here. The back part of the building was the living quarters of the farmer and his family as well as female servants, and was divided up into kitchen/living-room, pantry, bedrooms etc. In front of the forward gable wall, there was a large yard for dung, preparation of field work, e.g. harnessing of teams, or threshing of grain.

Nowadays, several modern buildings and structures are grouped around the yard, for example a dwelling house, garages for machinery and vehicles, stalls, barns, grain, bins, tanks for liquid manure etc. The old building is still integrated in

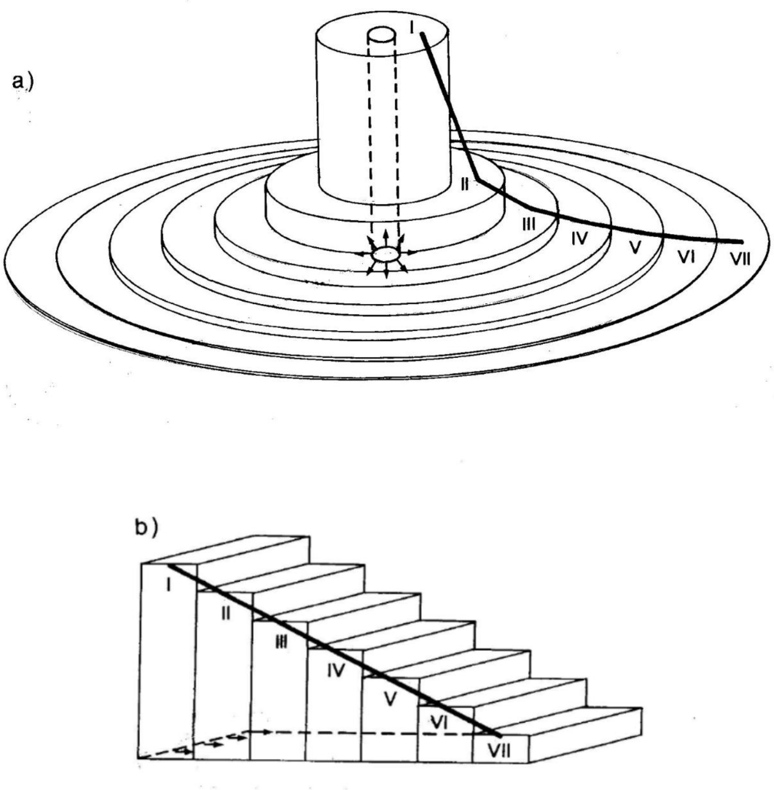


Fig. 3:
Long range effect (damped) under different spatial conditions
Initial region (locality) locally concentrated, embracing foreland, expanding in an outward direction (Umland).
Initial region (locality) extended in length, foreland formed on one side, uniformly wide towards the outside.
Each stage I, II ... has the same content in both models.
(Source: see "Notes on the figures").

this assemblage but now functions as a barn, repair shop, tool store, storage of farm products etc.

The rooms and buildings of the farmstead and the plots of land were arranged in such a way that work could proceed as simply as possible, i.e. according to the principle of the "shortest possible routes". This principle applies to the running of the entire farm. The area under cultivation is arranged so that the plots used most frequently and intensively were closer to the farm buildings while those used less frequently were located at a greater distance, where this was permitted by the quality of the land (e.g. marshy lowland or dry hill terrain). Closest to the farmstead is a kitchen garden and decorative garden where vegetables, fruit and flowers were cultivated for the use of family. Oaks, beeches, limes, chestnuts and spruce trees provide shade and protection from the wind. The farmstead is therefore surrounded by greenery while beyond this lie the fields. The more distant plots are used as pasture land for cattle in summer, as well as for meadows for growing hay as feed for the winter. The intensity of culivation is therefore greater in the vicinity of the farmstead, and becomes less with increasing distance.

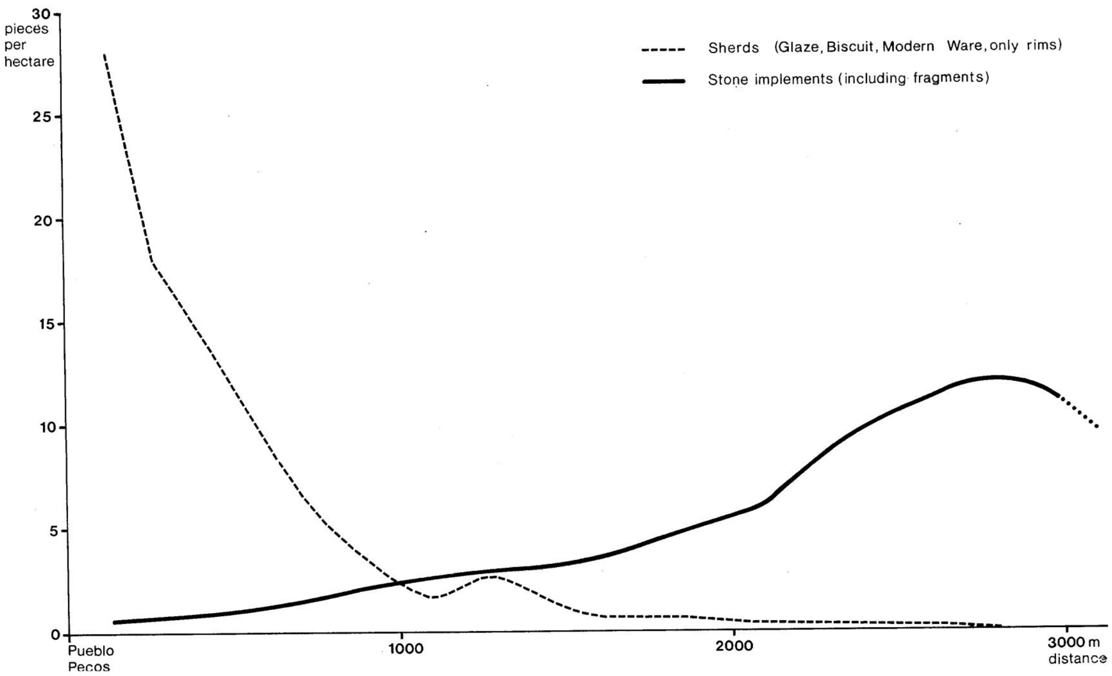


Fig. 4:
Density of sherds and stone implements found in fieldhouses at various distances from Pueblo Pecos as indication of the intensity of agricultural and hunting activity.
(Source: see "Notes on the figures").

The same tendency is apparent in completely different cultures. The intensity of cultivation also decreased at greater distances from the (now abandoned) Pueblo Pecos in New Mexico. The fields were cultivated and guarded from so-called field houses, which were scattered over the terrain. The occupation of these houses indicates the way in which the surrounding area was cultivated. The duration and frequency of their occupancy reflects the intensity of cultivation. This is shown by finds of ceramic materials used by the inhabitants. A study of the land around Pecos (1981) produced the largest amounts of ceramic sherds in the areas closest to the Pueblo (see fig. 4). By contrast, most stone tools (arrow heads, scrapers, knives etc.) used for hunting and preparing game were found further away from the settlement towards the uncultivated wilderness. This indicates that hunting was still the principal livelihood of the indians in the outlying districts and beyond.

2.2.4.2. Examples on a regional scale

Cities have divided themselves into districts or quarters with more or less homogeneous structures, e.g. in business, banking, governmental, and residential districts of varying quality and ethnic composition. Chicago (BURGESS 1925/67), Innsbruck (BOBEK 1928) and other cities were studied and mapped from a functional point of view by geographers and sociologists in the 1920s (see fig. 5). In the meantime, this type of division has become an accepted fact and is used as an effective instrument in town planning. All the elements of the same kind, industrial companies, shops, offices, inhabitants etc. are characteristic groups, i.e. groups or classes of elements with uniform features. Further examples are areas of uniform agricultural utilisation such as the wheat and sugar-beet producing area known as the Magdeburger Börde in Germany or the winter wheat cultivation area of the Great Plains in the USA. Such regions may consist of different characteristic groups or classes which can be analysed statistically from various points of view, e.g. industrial areas from the point of view of the products they manufacture, their size, the number of employees with a certain level of income etc. In this way, we obtain information on the functional division of land-use and the inhabitants. Regions which are homogeneous within themselves and characterised by one particular feature are equilibrium systems with reference to that feature.

These equilibrium systems are formed from outside. The energetic environment conditions are the same over the entire area concerned. With reference to our examples, these are the same local conditions in a city (e.g. property price), the uniform fertility of the land in agricultural areas etc.

At the same time, special attention has been devoted to equilibrium systems in which an additional horizontal "force" acts on the elements. Here, asymmetrical structures come into being, such as in economically motivated action projects. All the elements are directed towards one centre. A particularly good example of this is the town and its surrounding neighbourhood ("city-umland-system"; see also section 2.5.3.4). The commuters who have to travel into the town more frequently live close to the town than at greater distance from it. The densities are highest in the immediate vicinity of the town and decline rapidly at first as we move towards the countryside, and then with increasing slowness (see section 2.2.3, fig. 3a). A similar picture emerges in the case of migration of the population into a town, whereas in the other direction, the surrounding area closer to the town is used by its inhabitants for recreational purposes much more frequently than more outlying areas (unless these are particularly attractive). So, the catchment area (hinterland) of a town can be classified according to various criteria.

As we noted above (section 2.2.2) this is a cumulative effect. Each participant should be interpreted as an element which is trying to maintain itself and its desires in an energetic equilibrium.

The asymmetry of the structure in town and its umland also affects the economic use of the land. As with the above-mentioned farmstead, more effort is concentrated on utilising the space in the neighbourhood of the city as the initial locality (e.g. milk production, vegetable and flower cultivation in garden) whereas further away, fields are cultivated in a number of different ways (Thünensche Ringe ; v. THÜNEN 1826/1921). In the town itself, the geographical position of the various districts corresponds to the predominant ways in which they are utilised, e.g. central business district, residential area, industrial area etc. (see section 2.4.4.1). The intensity of utilisation is highest in the city centre, which is (hypothetically) easiest to reach from the remaining parts of the town and the surrounding area, but which also has the least space available for its users. In an outward direction, it first declines rapidly and then more slowly with increasing distance (see section 2.2.3) as we move towards the countryside. The town appears as the "central place".

Besides this horizontal differentiation, a vertical differentiation has also come into being, a hierarchy of central places (CHRISTALLER 1933; see section 2.4.4.1) where the higher-ranking places supply a larger surrounding area

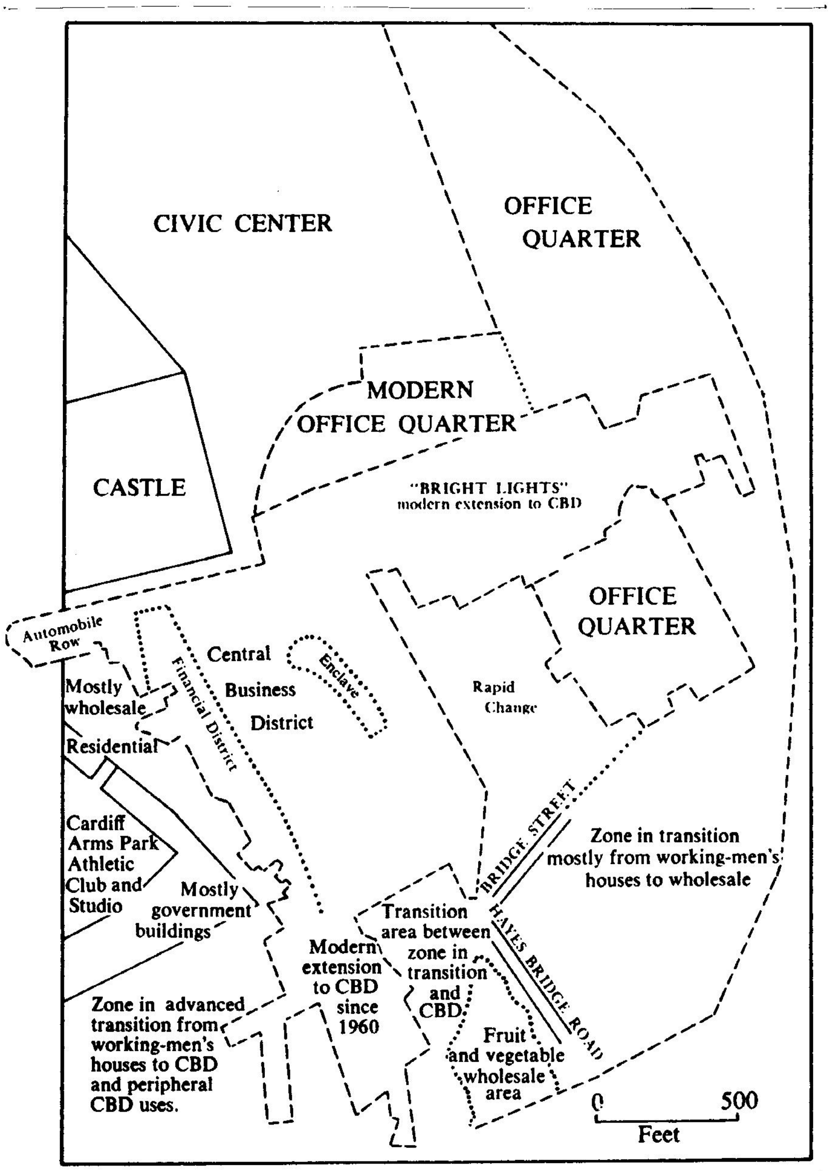


Fig. 5: *Urban regions in central Cardiff.*
Source: CARTER and ROWLEY, after MURPHY 1972, p. 99. (See: "Notes on the figures").

with an extensive range of services of every type (shopping precincts with department stores and shops, theatres, museums, clinics, regional and state authorities, airports etc.) while central places of lower rank provide more basic but more frequently required services (town hall, church, smaller shops with goods of everyday use, doctors, lawyers etc.) closer to the customer. Due to the advent of the private car, retailers and supermarkets are also spreading into smaller towns. The system of central places is subject to constant and sweeping change.

2.2.4.3. Examples from nature

The systems discussed above are anthropogenic structures. But the equilibrium systems also play a central role in inanimate nature. Examples of inorganic equilibrium systems of this type are known to us on a familiar scale and include dune areas, marshes, deserts, lake and river landscapes, oceans, but also geological strata, granite massifs etc. These are (typologically) homogeneously shaped forms and parts of the earth's surface or the upper lithosphere.

On a different scale, it can also be applied to liquids in their state of rest. All the molecules, each one individually, are undergoing violent movements (brownian movement), but the system as a whole is static.

These equilibrium systems can be enlarged or reduced in scale, elements can be added or taken away without the remaining parts being affected.

Central-peripheral arrangements are also demonstrated by, for example, volcanoes and the rocks of which they are formed, in particular the tephra. Close to the crater, large volcanic bombs are deposited while the number of finer particles increases with increasing distance until only dust is sedimented right at the outside. A similar formation is also seen in the case of alluvial fans. At the foot of the mountain, boulders and coarse rubble are deposited, giving way to gravel and sand as we move towards the plain, and finally depositing only silt and clay. The different particles can be interpreted as elements in equilibrium systems. They are controlled by a superior asymmetric structure in the energetic environment. It generates a gradient and initiates movement projects. Thus, the compulsion to execute the movement projects comes from outside. The elements move themselves (in accordance with gravity) in their resting position.

These structures can be attributed to a multitude of movement projects, which, through the specific fundamental conditions, result in uniformly structured large structures. Equilibrium systems adjust to the forces acting on them from outside. Either they or their elements seek the most favourable route in time and space, in horizontal balance. The system orders itself. Thus the equilibrium system proves to be an important component in ordering our reality.

2.3. Flow processes and flow equilibrium systems

2.3.1. The textile factory

The textile factory was in competition with other companies supplying similar products. Together with these, it formed (through its products) an objectively definable unit. This unit of companies was the supplying side of the market. Through the market, these companies received the demand for woven products from other companies which used them in other ways (further processing, sale etc.). This is the "superior environment". On the other hand, the textile manufacturers received the raw materials, electricity, water, etc. which they required for their processes from other companies. This is the "inferior environment".

The "whole" of the textile companies (weaving mills) formed a "compartment". A formation of this kind is distinguished by a material uniformity. They are all textile weavers (as elements). The number of companies may vary according to market situation. The important thing is that the compartment receives a demand (from the market) and attempts to satisfy it by supplying the products demanded. In order to do this, it requires, in addition to labour, raw material and energy.

The textile factory also received demand which it tried to satisfy, and it also requires raw material and energy. However (and this is the significant difference from the compartment described above) the company was a clearly delimited unit which was internally organised in such a way that it could produce itself. That was its intended purpose. We will return to this subject in the next section (see section 2.4).

In the weaving mill, the jobs (or action projects) were thematically ordered and, as already seen (see section 2.2.1), divided into specific departments such as stores, production and planning. These departments were spatially separate from one another, and each grouped together in certain buildings and rooms. It was expected of them by the company that they fulfil their task in co-operation with the other departments, i.e. in response to a demand, supply the demanded product, information or goods. From the point of view of the company, these were sub-systems, part of the organisation. To this extent, the departments were not in competition with one another.

However, taken individually, the departments could also be regarded as small compartments whose elements were the workers with their action projects. They competed with one another in the same way as the companies in the compartments. They had to maintain their position if they did not wish to fail or be removed. On the scale being considered, they and the earthbound artefacts used by them (buildings, rooms) represented the smallest units of utilisation. We will call these smallest units "topes". The term "tope" originates in the field of ecology and means a piece of landscape which is spatially delimited and unified in its ecological structure and which cannot be subdivided further within the scale concerned (LESER 1976, p. 212; SCHMITHÜSEN 1976, p. 207 called them "Fliesen", tiles).

2.3.2. General considerations

These relationships cannot be explained by the causal method or the functional resp. hermeneutic method. A precise examination of the processes and the links between the individual topes and compartments is required.

Compartments and topes:

In the topes, the action projects (see section 2.2) are bundled. In general, seen from outside, these are small areas which are uniformly utilised within themselves. Besides the departments in companies, they include various things such as spaces which are uniformly utilised or which serve a certain purpose (such as kitchen or living room), cultivated fields or routes used by traffic (roads and railways etc.). The uniform utilisation appears to be perfectly natural, but it is necessary to take a closer look. In the case of the departments, three main reasons can be identified:

1. The individual action projects can be conveniently joined together and channeled in this way. To allow the departments to fulfil their purpose as efficiently as possible within the company, they are equipped with various types of technical equipment (office machines, looms etc., see section 2.1.2).
2. The events and processes which occur in the topes depend on the information required for its task (e.g. the demand from the company management as the "superior environment").
3. The topes can only fulfil their task when they receive a regular supply of the energy they require (thermal energy, electricity, possibly also with raw materials). This in turn requires links with the "inferior environment", i.e. the actual source of energy in the wider sense.

What applies to the topes, also applies for the larger compartments, with the exception that, for them, there is no spatial limitation by a controlling institution such as management above, but an objective i.e. qualitatively determined limitation (e.g. the distribution of textile mills). Compartments must satisfy the demand through their supply with the assistance of efficient equipment. They must have access to the inferior environment supplying the energy and receive clearly defined orders from the superior environment (the market). We are dealing with a certain type of process and system. Whereas temporal-spatial, i.e. horizontal links make up the action (movement) projects and equilibrium systems, for this type, it is the energetic vertical connection between demand (in this case from the demanding companies or the market) and the source of raw material and energy, i.e. between superior and inferior environment. In this way, these systems are enabled to structure themselves in such a way that the flow of information as a consequence of the demand and the flow of energy as a precondition of supply can take place efficiently. Media and earthbound artefacts facilitate the processes and the adaptation of the systems to the environment. In this way, the system tries to maintain itself as an entity.

The individual elements, i.e. here the companies or individuals must adapt themselves accordingly. Anyone who is not efficient enough to compete, is eliminated. The efficiency in executing the processes and the pressure to adapt to the environments give the systems special characteristics and make them react to stimuli in a non-linear way. The independence of the systems thus expressed requires certain guiding mechanisms. Fluctuations are characteristic of the processes as is the type of diffusion of stimuli (demand and innovations).

Guiding "mechanisms":

The compartment guides itself vertically and horizontally.
Vertical control "mechanisms":

Let us try to understand what happens in the system between the superior and inferior environment. First of all, the compartment forms a link in a chain of compartments. The demand comes from the superior environment, i.e. from various compartments of the superior environment, and then passes through the system to the inferior environment, i.e. to various compartments in the inferior environment. (The elements of this inferior environment need this demand for their own existence, so they also demand on their part). From there comes the energy, i.e. in our case, the compartment formed by the textile companies demands the raw material, electricity etc. This energy is also fed through the system to the superior environment where it is supplied to the demanding compartments.

We can divide the entry of a stimulus into the compartment into 2 stages, which are the equivalent of partial systems (see fig. 6). The first partial system covers the compartment as a system (as a whole) with its elements (i.e. the companies) and is determined by the superior environment. The demand is entered into the system and then accepted by it. We describe this partial system as "system horizon". The individual elements have their own interests. They now have to pass the demand on to the inferior environment to allow sufficient energy (raw material) to be supplied by it. The elements form the second partial system, the "element horizon".

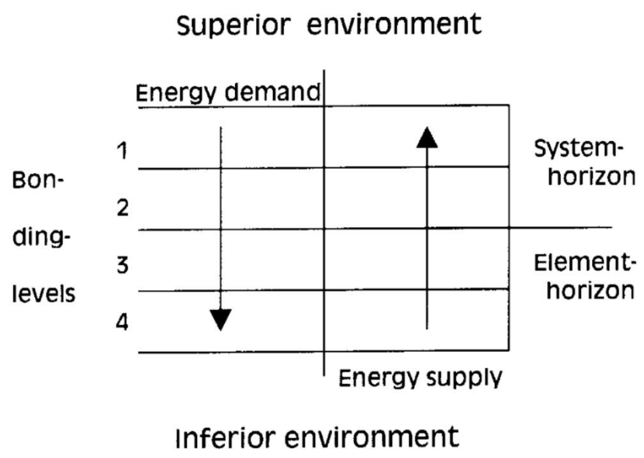


Fig. 6:
The four bonding levels (system horizon: entry and exit, element horizon: entry and exit) in the flow of information (demand for energy) and energy (supply of energy).
(Source: see "Notes on the figures").

For their part, these partial systems are again divided. First the demand enters the compartment as information from the market, the superior environment (step 1). The acceptance of the information is a 2nd step. The compartment limits itself in this way. Thus the system horizon consists of two different levels. This also applies to the horizon of the elements. First, there is a re-direction towards the inferior environment. The elements absorb the information and pass it on (step 3). It is then given to the appropriate department in the inferior environment (step 4).

Thus, we can distinguish four levels arranged hierarchically one above the other, which we will call "bonding levels". The flow of information with the stimuli takes place from the top in a downward direction, from the whole to the elements. A hierarchy is created which allows a precise control. On the other hand, the energy flows from the elements which fulfil the tasks, to the system as a whole which supplies the market. The inferior environment with its compartments decides independently whether and to what extent the demanded energy (raw materials etc.) is supplied.

Thus, the system is influenced on the one hand from inside, and on the other by the energy-supplying environment. As we will see later, the influence of the environment on the shaping of the system and process increases with growing complexity (see section 2.4.3, 3.2.4).

The horizontal guiding mechanism is quite different. In this way the compartments regulate themselves internally. The market demands specific products in certain quantities at different times. Many companies demand, many supply in competition with one another with the result that no central control can take place. To carry out their tasks leading to the delivery of the goods, the companies require time. The market changes constantly with the result that a temporal hiatus arises between demand and supply. [Only in recent times have companies attempted to bind their suppliers by contract ("just in time"). But that is no substitute for control unless the supplier is also taken over adminstratively]. The compartments with the companies competing against one another on the market can only check that the desired goods comply with the requirements of the demand with regard to quality and quantity when they are supplied. Demand and supply are then linked with one another and can be measured and compared. This is the feedback. If the expectations of the demander are fulfilled, the company receives the assurance that its supply is accepted. Other companies are perhaps unable to survive and are forced to give up. Thus, the number of companies in the compartment fluctuates. In this way, the system (compartment), i.e. the whole of competing companies producing the same goods, regulates itself.

Oscillations:

As stated above, on the free market, demand is frequently not equal to supply at the time of supply. Fluctuations take place through the delay intervening between demand and supply. Sometimes too little is supplied and then perhaps too much. Accordingly, the capacity of the companies as elements of the compartment, is sometimes fully stretched and at other times partially idle. As no complete balance can be established between demand and supply, the fluctuations are perpetuated. Here, we may speak of "oscillations". They force the system to accept a certain rhythm. In this way, demand and supply correspond to one another only in the mean.

Oscillations in the system permit innovations to penetrate it. In times of economic boom, the system is especially open to innovation and the introduction of an innovation gives the boom additional impetus. In this way innovations are frequently introduced at regular intervals which correspond to the oscillations (SCHUMPETER 1939/61; MENSCH 1975). On the other hand, times of slump are associated with crises and processes of elimination. In the case of our textile mill, the crisis in the industry on the 1970s altered the market to such an extent (foreign competitors were able to supply cheaper products through lower labour costs) that no further balance could be established and the company had to close down.

Diffusion:

As we have already seen, the company is in competition with many other companies in the compartment. In this sense, it is an element in the system which appears as a system unit through demand and supply. To return to the textile company, in the 1950s, it changed over to a new method of production. It replaced the old steam-driven looms with new looms driven decentrally by electric motor. A similar process took place at this time in many other weaving mills, allowing production to be organised more efficiently. This innovation passed from company to company in the compartment. When one company adopted the innovation and was successful, the others had to follow if they did not want to drop behind on the market.

Such innovations are generally spread through neighbourhood contact by being adopted gradually by those interested. This process of spatial spreading is termed "diffusion". The diffusion of an innovation is a process which changes the system. The system is moved from one state into another. As we will see later (section 2.5.3.2), the diffusion of innovations is a type of process which leads to social change, and on a more general scale, cultural evolution.

[The introduction of innovations within the companies takes place in a controlled way (non-equilibrium system, see section 2.4.2).]

In general, it can be said that a flow-equilibrium is sought, and that consequently the processes can be termed "flow processes" and the system a "flow equilibrium system". This is new in relation to the equilibrium system (see section 2.2). The flow of information and energy, the bonding levels, feedback, oscillation and diffusion are characteristic of this type of process or system. These are non-linear phenomena. We are at the third level of complexity.

The most important difference between the equilibrium system with action and movement projects on the one hand, and the flow equilibrium systems and flow processes on the other, is the inclusion in the flow of energy (and information) i.e. the system as a structure cannot exist in its own right, but only through the flow of information and energy from the environment. It is part of a chain of flow equilibrium systems which are coupled to one another through these flows. Conversely, it is the task of these systems to guide the flow of information and energy through control and self-regulation (as stated above).

Flow equilibrium systems are therefore distributing systems. The conversion of energy (raw materials) into products takes place in the non equilibrium systems (e.g. companies, see section 2.4).

2.3.3. The model

Through the bonding levels, the flow equilibrium system receives the possibility of the flow of information from the superior environment stimulating and controlling the flow of energy from the inferior environment. The system has created the hierarchy of bonding levels through the flow of information. First it opens up the system horizon, then the element horizon, in such a way that, as already indicated above (see section 2.3.2), four stages have to be traversed corresponding to the bonding levels. Within the bonding levels are internal (horizontal) diffusion processes which cause the gradual (i.e. bonding level after bonding level) vertical penetration of the stimulating demand (of information) into the flow equilibrium system (compartment). In this way, the system and its elements are linked with the flow of information. This leads to the hierarchical organisation of the system structure.

This 4-stage process can be described using exponential formulae. The same applies inversely for the flow of energy which proceeds from the inferior environment via the fourth to the first bonding level to the demanding superior environment. Through the flow of energy, a new material-energetic component enters the process. This means that the energy is not only put in as an impulse (as in the first level of complexity, see section 2.1.3), but as a substance demanded by the inferior environment. We follow the flow of information:

1st bonding level:
The demand is entered into the flow equilibrium system as a whole. The quantity of those potentially interested is registered. At first, the elements are involved as such without being bound to the system. Here the formula of "unbraked" positive exponential growth applies (see section 2.2.3):

[7] $$N_n = k * N_{n-1} \quad \textit{adopters}$$

2nd bonding level:
The quantity of interested elements is now limited. Thus, the diffusion of the demand is also limited. The positive exponential development is braked by a negative exponential counter trend. This can be done in two ways. Either the development is limited by the inferior environment, i.e. a negative exponential term $M_n = M_{n-1}/a$ hampers the increase with each step (a constant):

[8] $$N_n = N_{n-1} + O_n;\ O_n = O_{n-1} * M_n;\ M_n = \frac{M_{n-1}}{a}\ adopters$$

Or the development is limited by the superior environment; the "Logistic function" is applied (see fig. 7). Then the size of the system is assumed to be known. The constant K defines the quantity of the potential adopters (a constant):

[9] $$N_n = N_{n-1} + N_{n-1} * \frac{K - N_{n-1}}{a}\ adoptors$$

In both cases, the graph is S-shaped.

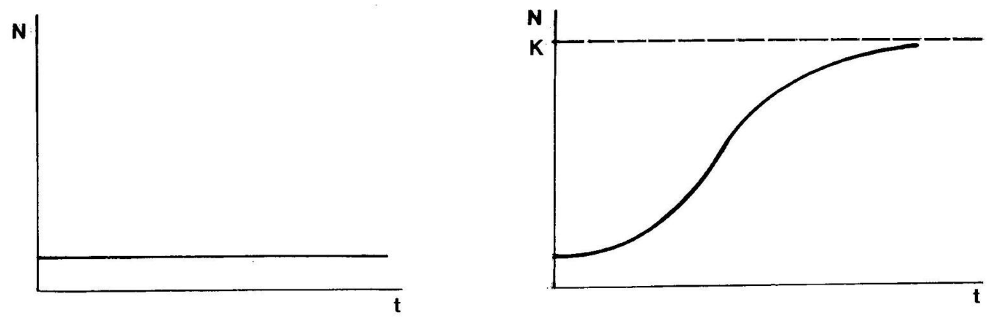


Fig. 7:
Conserving and changing process in the flow-equilibrium system.
In the conserving process (left) the amount of production or the number of elements N remains constant over the course of time, whereas if a change takes place, (right, "logistic curve") the value of N has an S-shaped curve, i.e. leads upwards from the first state until it has reached a second state at value K. The diffusion of an innovation is a changing process.
(Source: see "Notes on the figures").

3rd bonding level:
At the 3rd stage, the growth of demand is received by the elements which require it for their own existence, and then it is removed to be transmitted to the inferior environment.
Thus, the system-internal increase of the positive exponential development is not only slowed down negative exponentially (by the term M_{n-1}/a, as at the 2^{nd} stage), but additionally reduced

by a term N_{n-1}/b. The result is a hill shaped graph (*n* is the x-variable):

[10] $$N_n = N_{n-1} + O_n - \frac{N_{n-1}}{b}; O_n = O_{n-1} * M_n; M_n = \frac{M_{n-1}}{a}$$ *adoptors*

(*a* and *b* are constants).

4th bonding level:
Each element of the system must obtain raw material etc. from the elements of the inferior environment. Thus, two systems oppose one another, system *A* and system *B*. The demand from system *A* is passed to the inferior environment (system *B*). This responds. System *A* and system *B* are interacting with one another. The elements *N* constitute the demanding (demand stimulating "transmitting") system *A*, and the elements *M* the demand receiving (and energy supplying) systems *B* of the inferior environment. Because the providing of the demanded energy by the inferior environment needs time, transmitting and receiving are delayed. Oscillations are created which may be described by the Lotka-Volterra relations (predator-prey relations; LOTKA 1925/56, p. 88. See fig. 8):

[11]
$$N_n = N_{n-1} + \frac{N_{n-1} * M_{n-1}}{a} - \frac{N_{n-1}}{b}$$ *adopters A*

$$M_n = M_{n-1} - \frac{N_n * M_{n-1}}{c} + \frac{M_{n-1}}{d}$$ *adopters B*

(*n* = temporal steps, i.e. the *x*-variable; *a, b, c, d* constants).

These oscillations give the processes in the system their continuity and their rhythm, the flow-equilibrium systems regulate themselves by attempting to keep demand and supply in a flow equilibrium with the help of feedback mechanisms (see section 2.3.2).

Through these oscillations, the inferior environment is stimulated, activated as an external energy source, and coupled to the system. It supplies the energy. The flow of energy takes place in an upward direction, from the bottom to the top. As already stated (see section 2.3.2), the process passes through the bonding levels in the opposite sequence. At the transition point from the first bonding level to the superior (demanding) environment, the feedback takes place through comparison of the supply with the demand. Through its ability to regulate itself, the system demonstrates independence with reference to the externally guided equilibrium system and in particular with reference to the solidum (see sections 2.2 and 2.1).

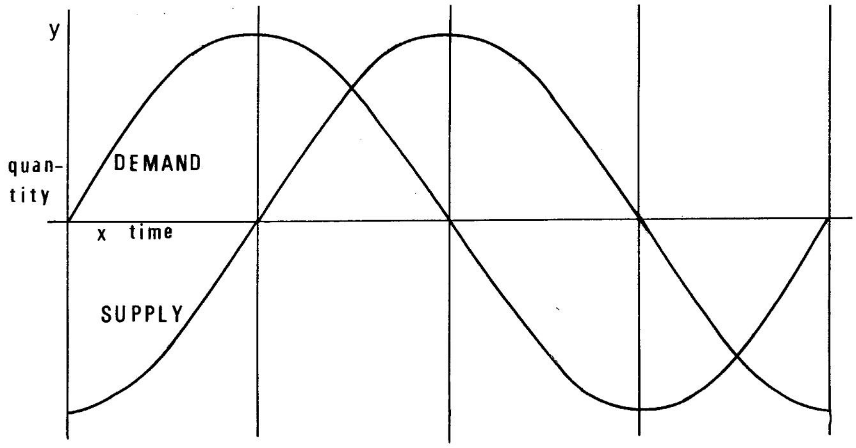


Fig. 8:
Oscillation of a flow-equilibrium system.
The demanders and suppliers (e.g. in a market) stimulate each other mutually. The first group demands energy, the second group supplies the energy. As the supplying group requires time to make the energy available, a delay occurs which leads to oscillations (around a central value). (Source: see "Notes on the figures").

2.3.4. Other examples

Flow equilibrium systems are ubiquitous. Their study depends on the possibilities available and these are dependent on the constitution of the system. Frequently, one has to deal with complex systems consisting of different types of compartments. In such cases, these compartments must be analysed as component parts of the entire system. In complicated ecological, social and economic systems, some compartments can be identified. They occupy certain positions in the flow of energy (e.g. biotic producers or consumers in ecosystems, institutions in social systems, economic branches). Here, input-output studies (among other things) would seem to be the obvious way to proceed.

If however the individual compartments can be isolated, many of the processes within the system can be studied, in particular when the individual elements are identifiable and can be counted (e.g. persons in their roles, companies in the compartments as described above). These include the chaotic systems which in their turn lead to the systems which are the objects of research into complexity. Here, simulations are important instruments of analysis.

2.3.4.1. Complex systems consisting of different compartments

First of all, let us look at the case where the individual compartments can only be analysed in combination with other compartments. They each occupy their own place in the flow of energy. The entire complex being examined generally consists of many such compartments. These are flow equilibrium systems in the flow of energy whose input-output ratio and other characteristics can be studied. Through their own feedback systems, these compartments are non-linear, i.e. the output is linked to the input in a non-linear and frequently unpredictable way. Thus, the fact that flow processes entail their own existence is the central point for consideration. Several disciplines are involved in the analysis of such systems.

The cultivation of a field:

Let us look at a simple case first. The ecosystem of a tope is stimulated by a farmer in order to obtain certain products. The soil over a certain clearly delimited area, e.g. a bed, a field, meadow etc. is tilled by the farmer. In this case, a field is planted with a crop (rye, oats, turnips etc.). The method of working the soil and the harvesting the crop are specific to each field and each type of crop. It is not to be taken for granted that the soil should yield a crop. The soil of a field is an ecosystem which consists of billions of living organisms and a multitude of compartments. The farmer must cause it to produce the desired crop in accordance with the demand and the labour at his disposal, using certain techniques and by planting seed or plants. The farmer is primarily interested in the ratio of input to output.

The fields are delimited on the land mostly in such a way that they have natural homogeneous characteristics (e.g. sand content, moisture, slope of terrain etc.). The farmer tills the soil to make it produce crops which are then harvested. Thus, crops are demanded and this is "communicated" to the soil by special means. The soil then provides the crop as desired. The ecosystem for its part has its own source of energy in the inorganic parts of the soil and the subsoil. This is the inferior environment.

First of all it is ensured that the requirement of the farm as the superior environment is input into the field. This includes the working of the soil (fertilising, ploughing, harrowing etc.) and of course the sowing of seed. For the ecosystem of the soil, this is the information to supply a certain crop. At the same time, the inferior environment of the ecosystem is supported as energy supplier through fertilisation.

Through this information and the material support, the ecosystem of the soil is aligned to the requirements of the farm. Thus, the flow of information in this case is the transfer of the demand to the field. In this tope, the information is distributed to the various parts of the ecosystem with its purely chemically reacting substances, the plant, animal and microbe populations. As such, however, these react independently.

The ecosystem of the soil of the field responds to the information by providing nutrients to allow the seed to flourish. The growth of the crop in the cultivated field is accompanied by other activities such as the removal of weeds or pests. The crop is harvested i.e. removed from the field by harvesting machinery and taken over by the farm system and stored there until they can be supplied to the market. This is the flow of energy. The energy, i.e. the crop comes from the ecosystem (and its inferior environment). Due to the fact that the flow of information into the system is increasingly accurate (i.e. improved methods of working the soil), the flow of energy becomes more abundant. [For the problem of overcropping, see section "Rotation"].

As already noted, every flow equilibrium system depends on the supply of information and energy, otherwise it will disintegrate. Both have to be supplied by other systems. This opens up the way to understanding the food and production chains as they are studied in ecosystem research and economic sciences.

Complex ecosystems:

In research into ecosystems, the complexes are divided into as many quantifiable compartments (as partial or sub-systems) and other components as possible, e.g. in aquatic systems into the different types of flora and fauna (but also temperature, chemical composition, suspended material etc. are measured), in order to understand how they are co-ordinated and linked together. Terrestrial ecosystems are studied in a similar way. The flow of energy is seen primarily in the food chains and takes place between communities of the same species ("area systems"; MÜLLER 1981) which occupy their ecological "niches", but also between the living creatures and the inorganic environment. The plants withdraw nutrients from the soil or the water and they themselves form nourishment for animals. Consequently, we may use the term "producer" (plants, suppliers) and "consumer" (animals, demanders) in this context also. Certain autotrophic plants provide the nourishment on which certain herbivore species depend, while these species may themselves be eaten by others (carnivores). The important thing is to realise that the ecosystems are not only flow equilibrium systems. Ecosystems also contain conversion, production and self reproduction. In this way they also belong to a higher level of complexity (see section 2.6; fig. 33).

Complex economic systems:

Economic systems can be analysed in basically the same way, e.g. the development of towns. A number of variables (inhabitants, birth rate, migrations, occupation, unemployment, industrial production, tax yield, dwelling construction, slum development etc.) were combined as compartments or other components by FORRESTER (1969; 1968/72) to form a model with which development can be simulated. The feedback mechanism is decisive for understanding the processes in the system. The present and future behaviour of the system is affected by its own past. The feedback loops use the results of previous actions as information to regulate future actions. This information may be wrong, but it is still decisive for future behaviour. The availability of resources also affects the feedback loop. In addition, constants are involved which mark the objectives and the process of time. In creating the model, different feedback loops generally have to be linked to one another. At the same time, it has to be clear how the internal hierarchies are made up. The system changes step by step and the changes are accumulated.

This model has also been used to simulate mankind as a whole and was used by the "Club of Rome" in 1972 as the basis for its assessment of the state of humanity on the earth with reference to the resources available. Among the parameters used were the population, mining, industrial and agricultural production, service industries, the quantity of known mineral resources, environmental conditions etc.

Complex social systems:

Because of their many different forms, social systems are particularly difficult to analyse. A number of qualitative theories have been developed by the social sciences dealing with the complex structure of society on the basis of the system theory. LUHMANN (1984; 1998) in particular developed an elaborate theory which has had considerable influence on the theoretical sociological discussion. For him it is especially the problem of differentiation of the social system, i.e. its formation in its environment, which is decisive.

In general, it can be said that Luhmann illuminates already familiar terms and other terms used by other authors in the social sciences from a number of angles and arranges them in such a way that they can be combined with one another without contradiction. The selection is made by himself. Some of the terms are taken from the natural sciences and interpreted in his sense. This means that the theory can only be checked to verify its intrinsic accuracy. Frequently, the terms are not defined in the way originally intended by the issue in point. Thus the term "autopoiesis" is not defined in its genuine scientific sense (MATURANA & VARELA 1984/87; see section 2.6.2), and the expression "self-organisation" also appears rather vague. The processes do not arrange their time budget durably as with the non-equilibrium systems. No clear distinction is made between flow-equilibrium and non-equilibrium systems and it is therefore not apparent how the systems are structured. For this reason, Luhmann's ideas do not represent a true stimulus to the natural sciences, as they are much too vague for these disciplines.

2.3.4.2. Processes in individual compartments

The inductive analysis of the individual compartments is more promising, and impressive results have already been achieved here. They can be linked to specific characteristic phenomena, to oscillations, rotation and diffusion. From here, the path leading to complexity research is short.

Oscillations:

The delayed reaction of the supplying inferior environment to the demand from the superior environment creates fluctuations which can develop into periodic oscillations. The fluctuations in the work of farmers in the day-to-day and seasonal rhythm may be interpreted as the oscillations of a self-regulating system where the rhythms dictated by nature provide the general cadence. Demanders and suppliers can also stimulate one another in other ways so that oscillations of a lasting nature may commence and take on a certain rhythm. This capacity for rhythm applies to almost all flow-equilibrium systems, wherever certain goods are demanded by the superior environment and supplied by the inferior environment. The duration of the period may be days, months, years or decades. Many economic cycles can be interpreted as oscillations of this kind.

The Pueblo Pecos (New Mexico) provides an impressive example of such oscillations. Studies of the terrain show that the area under cultivation expanded and contracted over a period of around 60 years (see fig. 9). With a slight delay, the population fluctuated in the same way, according to the written sources for the later period (KESSEL 1975). [Unfortunately, the two graphs coincide only for a few decades, as population counts only began with the period of Spanish rule from the 17th century onwards. On the other hand, the population of the pueblo declined considerably during this time, until the survivors were forced to leave the village and settle elsewhere. However, the tendency as such is clearly distinguishable]. It can be concluded that the economic production interacting with the number of consumers resulting

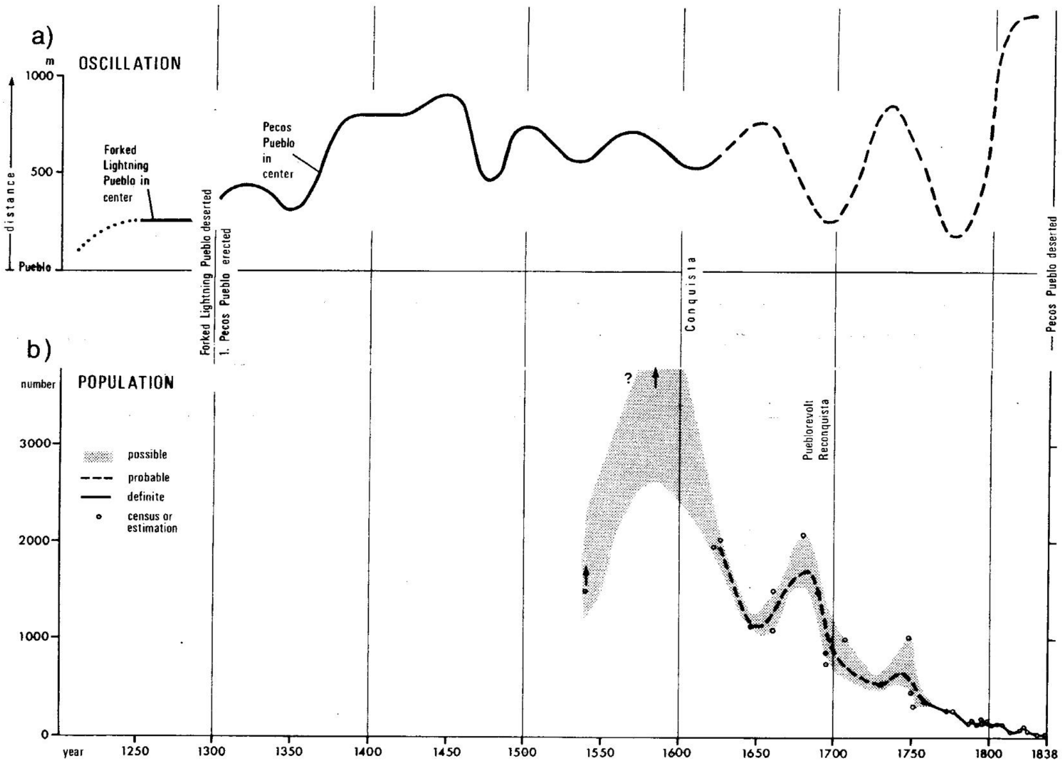


Fig. 9:
The deserted Pueblo Pecos (New Mexico), oscillations in field exploitation.
a) Single houses at a medium distance from the pueblo during different periods. Dating based on finds of sherds.
b) Population numbers.
For the time before 1620 (Conquista), the sources for the utilisation of the land are reliable. Thereafter, the documents are less clear. By contrast, the population figures are only certain for the period after 1620. Before this, only unreliable estimates exist.
(Source: see "Notes on the figures").

from biotic reproduction, was the cause of these oscillations. Expansion of the land under cultivation prompted (with a certain delay) a rise in the population. This in turn led to over-exploitation of the land, decline in fertility (as shown by soil erosion) and lower crop yields resulting in turn in a decline in the population, after a period of delay.

The process of colonisation is also subject to rhythms of this kind. For example, the above mentioned Spanish colonisation in the living space of the Pueblo Indians (New Mexico) took place

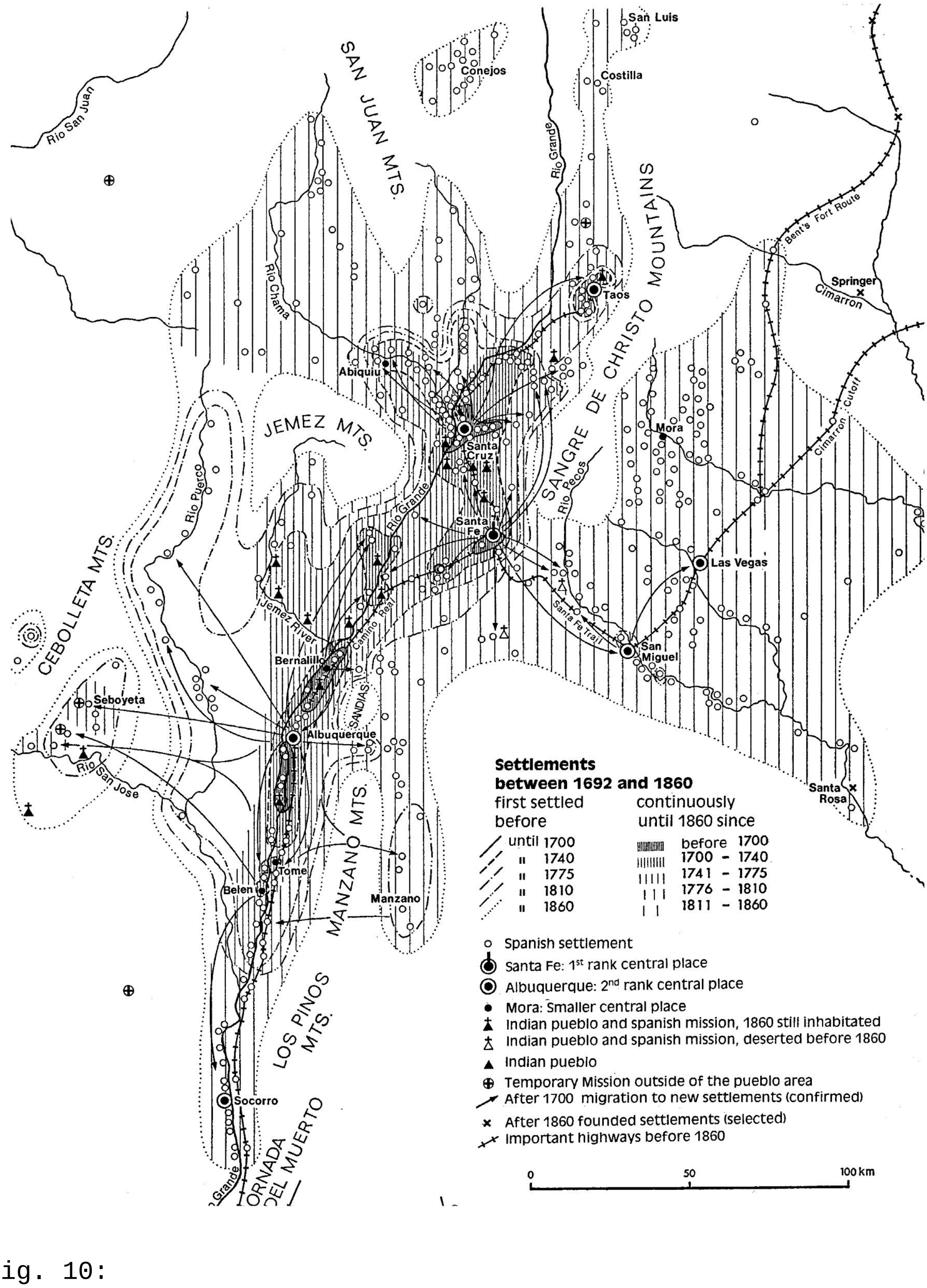


Fig. 10:
The Spanish colonisation of New Mexico 1692 - 1860.
(Source: see "Notes on the figures").

in waves (each of which lasted about 50 years) from the population centre of Santa Fe (see fig. 10). The reason: as the number of inhabitants increased exponentially, the supply of foodstuffs declined. The requirement for additional land increased, which produced an increase in colonisation. As the crop yields rose, the pressure to acquire new land ebbed, but as the population increased, another phase of expansion became necessary and so on. The social and economic conditions changed with every oscillation phase which meant that new forms of settlement came into being.

The Conquista began around 1600 with the foundation of mission stations in or near the pueblos. Following this, the haciencas were established. A period of resistance by the indians led to the withdrawal of the Spaniards in 1680. The Reconquista took place in 1692. Small farming and cooperative settling started, first with wide strips, respectively blocks and strips, later with rows of blocks. In the 19th century, individual structuring won through in settling; small farm groups and block fields - besides strips - became typical (see fig. 11). The colonisation process proceeded according to specific rules. Dot patterned, clone-(ramification-) and cluster-colonisation followed each other.

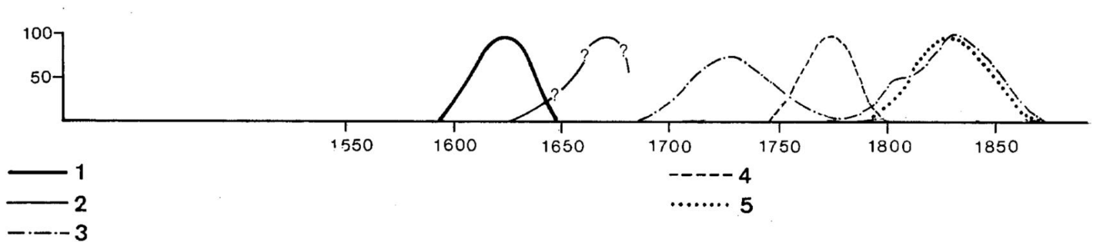


Fig. 11:
The phases in the colonisation of New Mexico by the Spaniards 1598 - 1860.
Legend: 1: Pueblo missions, 2: Haciendas (uncertain data), 3: Settlements with regular wide strips, 4: Settlements with rows of blocks, 5: Irregular small farm groups and block fields.
(Source: see "Notes on the figures").

Thus, the oscillations are associated with innovations (new forms of settlement). This also applies to economic cycles (SCHUMPETER 1939/61). In many cases, the innovations are spread at the time of the economic revival, even though the inventions themselves may have been made some time before (MENSCH 1975), which means that the diffusion of the innovations also takes place in waves.

Oscillations and waves are also widespread in the natural world. The biology of populations provides us with many such examples. The extent to which similar phenomena in the inorganic world are attributable to the same pattern of processes and systems as in human society, cannot be discussed here. There are simply not enough detailed studies.

Rotation:

Let us return to the farm. The soil is only able to support a population as long as its fertility is maintained, i.e. its ecosystems remain intact. Through skilled cultivation, the farmer is able to take the necessary energy from the soil over longer periods of time. Through the cultivation rhythms (oscillations) dictated by the days and seasons, the soil is able to recuperate and prepare for a new phase of production. However, in the long term, this in itself is insufficient. Besides the use of fertilisers, it is also advisable to change the crop because the different plants utilise different spectra in the scale of mineral nutrients in the inferior environment. In most cases, crops are altered in a certain rhythm, e.g. tubers (potatoes, turnips) and cereals. This regularly recurring change is termed "rotation". It is a temporal-spatial sequence in cultivation, because each field, as a tope, produces a different crop at (generally) yearly intervals (unless a forced monoculture takes place through intensive use of fertilisers). The farmer then changes the previous crop to another field. After a number of years, the sequence is concluded and a new one begins. In this way the ecosystem in the soil can recuperate and is protected from over-exploitation. The spatial and temporal character of the processes is seen in this rotation. In pre-industrial times, the principle of three-field cultivation was widespread. The open field belonging to the village was divided into three parts and each peasant had his share of each part. A process was agreed among the inhabitants of the village whereby winter and summer crops and fallow periods alternated.

In addition to this short-term rhythm of rotation, long-term rotation cycles are also known. The rhythmic expansion and contraction of arable land in Pecos (see above) was associated with rotation (see fig. 12). In each of the expansion resp. contraction phases, the arable land was shifted slightly away from the previously used area which was now damaged by erosion, with the result that with each expansion of the area under cultivation, new terrain was developed. This was repeated several times while the main area of cultivation moved around the pueblo in a tangent.

Unfortunately, very few studies exist on the phenomenon of rotation, although corresponding observations could be made in completely different environments and orders of grandeur. In 1962, the author made a study of rotation phenomena in migration and movement of traffic and commuters in the vicinity of a number of German cities. With the assistance of statistical analysis, it was possible to compensate spatial imbalances produced among other things by the differing sizes of the statistical areas. It was shown that the movements had a latently tangential deviation from the anticipated radial direction leading to the centre.

On a higher scale, we see that the regions initiating the styles in European art in modern times (Italy, France, Germany, Netherlands etc.) shifted several times. Thus, gothic

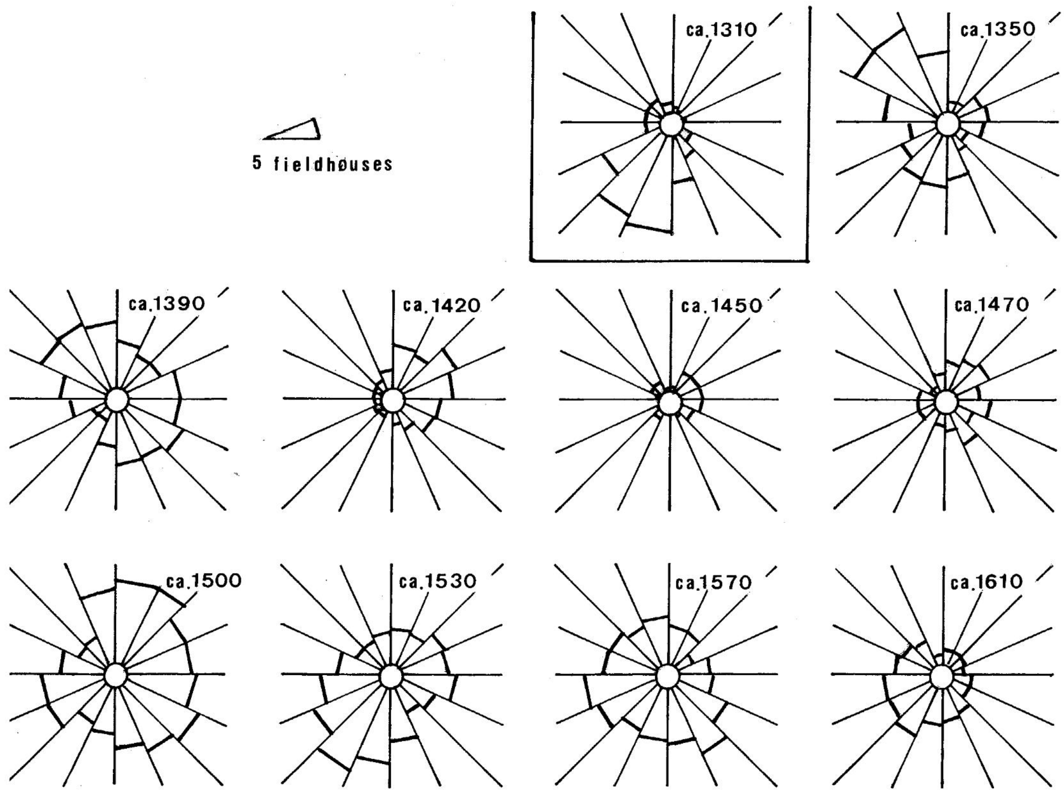


Fig. 12:
Rotation in agricultural land of the abandoned Pueblo Pecos (New Mexico) before the arrival of the Spaniards (Conquista).
Using the number of datable field houses it is possible to determine (using statistical evaluation of the soil quality) in which sector (16-part rose with the pueblo at the centre) the land was used more or less intensively in which years. It can be seen that in the period between 1310 and 1610 A.D., the main area covered by fields shifted in a tangential direction (on average to the right) in a series of oscillations lasting on average 60 years.
(Source: see "Notes on the figures").

architecture spread to other parts of Europe from France, Renaissance and Baroque styles from Italy, the music of the 18th and 19th centuries from Germany, Austria etc. However, the closer we approach the present, the more differentiated the form of artistic expression becomes and the more difficult the interpretation.

It is also difficult to interpret the way in which the centres of power in Europe took one another's place over the centuries; Spain, Austria, Prussia, France, England, Germany and other states have all enjoyed positions of pre-eminence in modern times.

Diffusion:

As described above, changes of state take place in flow-equilibrium systems (unless they are carried out in a controlled way, e.g. in factories) through the diffusion of

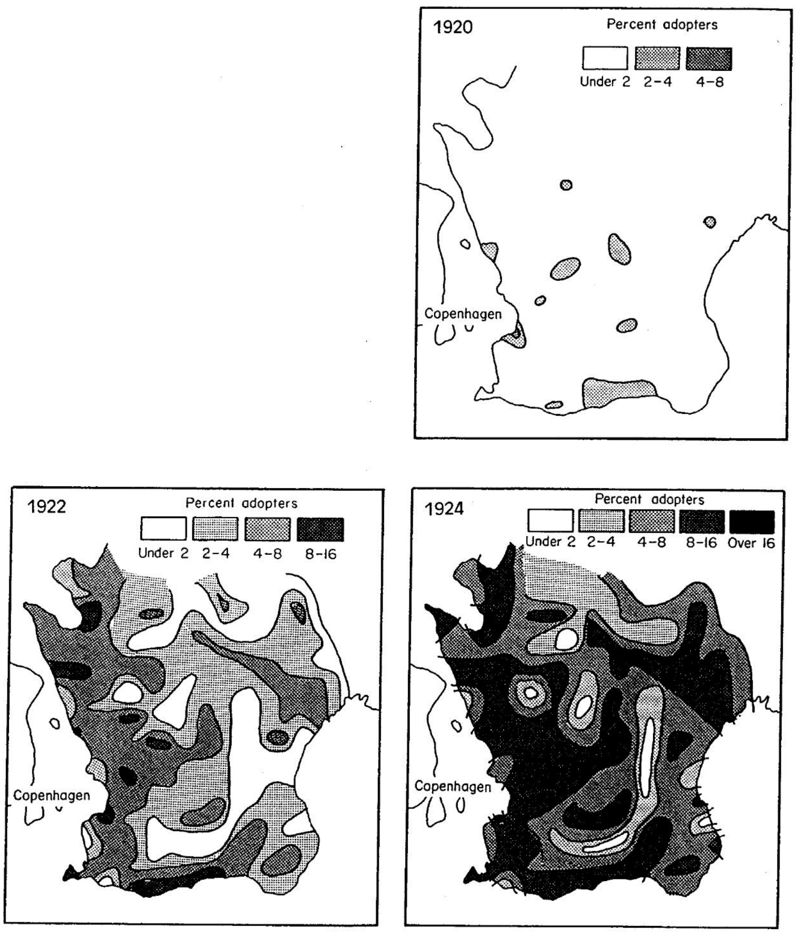


Fig. 13:
Diffusion of the automobile in southern Sweden 1920-1924.
Source: HÄGERSTRAND (1952); after ABLER, ADAMS and GOULD (1971, p. 396). (See "Notes on the figures").

innovations. The diffusion process is irreversible, because knowledge which has been released or diffused can no longer be taken back. Examples are the diffusion of cultivated plants and domestic animals over the earth since the neolithic age (SAUER 1952), and in more modern times, the spread of technical inventions such as that of the automobile (HÄGERSTRAND 1952; see fig. 13). The division of history into periods is based to a considerable extent on the adoption of innovations by peoples and civilisations which then gave rise to structural changes and developments (e.g. Renaissance and Reformation, styles in literature and art). In many cases, these processes of diffusion can be linked to oscillations (see fig. 14).

The diffusion processes are also omnipresent outside social and economic reality. An area of application of importance for medicine is the spread of diseases (pandemics), the study of which is crucial to their prevention. Ecologists study the spread of new species of plants and animals within ecosystems (e.g. the introduction of the rabbit in Australia or the horse in North America). The flow equilibrium of a system can be substantially altered by diffusion processes of this kind.

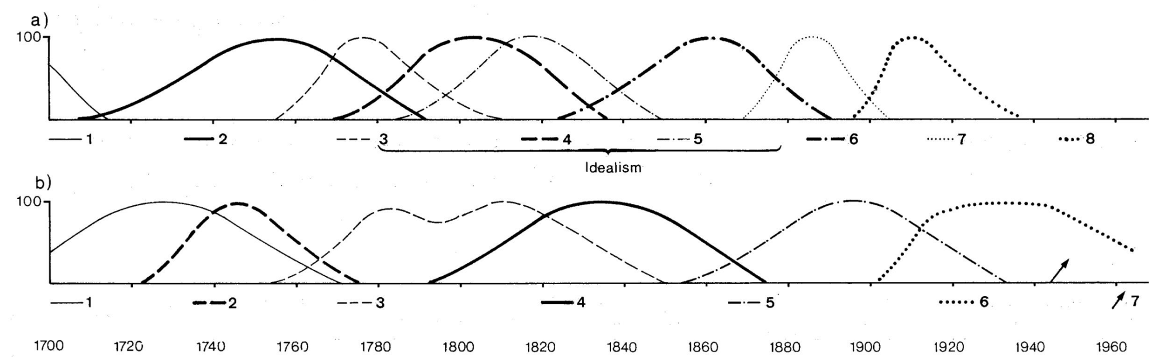


Fig. 14:
Diffusion of art styles in Germany and France since 1700.
Over 3 decades smoothed. Respective maxima of the change = 100.
Literature in Germany:
Legend: 1: Baroque, 2: Enlightment, 3: "Sturm und Drang", 4: Classic, 5: Romantic, 6: Realism, 7: Naturalism, 8: Expressionism.
b) Architecture and painting in Germany and France:
Legend: 1: Baroque, 2: Rococco (in Germany), 3: Classicism (in France and Germany), 4: Romantic (in Germany), 5: Impressionism (in France and Germany), 6: Modern Art in Europe, 7: Contemporary Art.
(Source: see "Notes on the figures").

Colonisation also takes place by means of diffusion, e.g. the Spanish colonisation of New Mexico (see above, fig. 10). In this way, anthropogenic spaces were created. These spaces occupied by flow-equilibrium systems are affected by the environment (e.g. quality of soil, preferred sites) with the assistance of the diffused system itself. The elements, i.e. the farms, are situated in flow of energy and they have to ensure that they maintain a flow equilibrium between demand for and supply of foodstuffs. If the flow equilibrium was seriously disrupted by a decline in the flow of energy from the inferior environment, e.g. if the soil did not produce sufficient yield, the farms would have to give up. This was the reason for the abandonment of several previously settled areas in New Mexico. The irrigation of the fields became increasingly difficult.

A complete different picture appears with colonisation where population growth suddenly accelerates, i.e. where the demand for new land outstrips the ability of the system to provide it.

Let us again look at the colonisation of New Mexico by the Spaniards. As we saw (see above, oscillations), new forms of colonisation were used with each wave of diffusion. Following the Reconquista in the period up to around 1750, the process of diffusion was generally carefully planned. The settlements were accurately surveyed (wide strips and blocks with strips). Then, up to approximately 1800, the colonisation became much simpler in form, i.e. more irregular (rows of blocks). The last wave of colonisation in the 19th century shows signs of increasing disorder. Many settlements (small farm clusters and block fields), show no trace of centralised planning. Finally, the colonisation process shows a complete absence of control. Settlements sprang up where space was available and where it was most suitable for the settlers, i.e. where water was available. The population of New Mexico underwent an explosion between 1800 and 1850 (the territory was annexed by the USA in 1846), increasing from 20.000 to 60.000 in this period. Apparently, the governing hand of the administration (as manifestation of the system) was no longer able to resist the pressure of the increasing population and control it in well ordered channels. This phase of the development shows the first sign of a chaotic pattern.

We will return to this problem later (see section 2.4.3.1).

2.4. Conversion processes and non-equilibrium systems

2.4.1. The textil factory

The various departments of the textile mill with its earthbound artefacts (topes, see section 2.3.1) were organised in relation to one another in such a way that they allowed the smooth co-ordination of the action projects of the individual workers. The factory was the place of economic activity of a group of workers who carried out tasks with one another, thereby shaping the framework for their own activities. The earthbound artefacts formed the framework by means of which organised work was made possible.

The workers communicated with one another on the basis of a division of labour, i.e. different information and materials were altered and joined to form new products (the woven products) which could be sold on the market. Each piece of textil material was the product of many units of information and actions, which were precisely co-ordinated with one another in time.

A clear, balanced and understandable structure of work and inspection formed the framework necessary for production. Precisely this is the advantage of division of labour - that the action projects and the flow processes in the departments are perfectly co-ordinated with one another in time. The preceding work and raw materials required for the production are available at any time with the result that there are no difficulties in adaptation as in the self-regulation of the flow-equilibrium systems (see section 2.3.2), and the various tasks dovetail directly into one another and follow one another without delay.

The structure of control and inspection requires a hierarchy within the mill. The board of directors, of which the proprietor was the chairman, represented the mill as a unit, to which the workers were responsible. In an abstract manner of speaking, the system was opposed by the elements. The workers were able to defend their interests through their representatives (e.g. when excessive demands were made on them). The stimulus (information) for the processes was received by the board of directors and the commercial administration from the market (superior environment) in the form of demand. Here, the decisions were taken and planning carried out while the actual physical work took place afterwards in the other departments of the mill. The suppliers (as inferior environment) supplied it with raw materials, electricity, thermal energy, water etc.

As a production company structured on the basis of a division of labour, the textile mill as a structural type was on a level with large industrial companies, farms, medical clinics, food stores, lawyer practices, public offices etc. From an economical point of view, these were companies ("Betriebe") (or offices). However, the fact can be emphasised that the companies (or offices) were shaped co-operatively by people, i.e. by a population. This is the view taken by social scientists and from this point of view, we may speak of "organisates". In contrast to the flow-equilibrium systems (see section 2.3), these are characterised by the fact that they are structured in a way which is differentiated qualitatively, and that they manufacture products using a specific process. Self organisation is part of this.

It is only possible to explain the organisation and shape of the organisate by taking the internal processes into account. The persons engaged in the organisate textile mill represented the "carriers" of the processes, i.e. they permitted the practical implementation of the systemic links and process sequences with the assistance of the media and earthbound artefacts (see section 2.1.2). As sub-systems, the departments played a kind of mediating role between organisate and individual worker. They had certain well defined tasks for the organisate and the individual action projects were concentrated in these accordingly. As already described, their spatial arrangement in the factory was of considerable importance.

2.4.2. General considerations

As a general rule, the action projects are arranged in time and space in such a way that they are particularly effective for the organisate. This means that they were joined up to form a unified process which made it possible to fulfil the demand imposed from outside, i.e. by the market. This organisation requires reliability and punctuality on the part of the workers. Each worker must submit to the requirements of the whole, otherwise the division of labour cannot work. In contrast to the self-regulation of the flow-equilibrium systems, this is a kind of control made possible by hierarchic organisation. The result of the process is the product.

Products can be defined as energy (matter) loaded with information. In this way, the organisates intervene between the market (the superior environment providing the information) and the supplier of raw material (the inferior environment providing the energy). As already outlined (sections 2.3.1 and 2.3.2), they are parts of the compartments, i.e. the flow-equilibrium systems, and like these are located in the flow of information and energy. However, these flows are given specific form by the transformation of energy or raw material into products so that they can be passed on to the markets, i.e. to the demanders, in precisely the form required. Put more generally, the material in the form of products becomes precisely "fitted", i.e. qualitatively specified transportable energy (for accuracy of fit, see VOLLMER 1985/86, I, p.59 f.).

The self-regulation on the market is borne by the self-interest of the supplying organisates which seek to gain an advantage from the relationship. In every organisate the tendency exists to expand itself or its influence in order to increase its productivity. This takes place primarily to maintain its position on the market as the superior environment with reference to competing organisates. Thus it attempts to minimise the input (from the inferior environment) and maximise the output (to the superior environment). In this process, organisates also tend to organise themselves in such a way that the flow processes can be linked together as well as possible. The (spatial) self organisation serves to minimise the consumption of time and energy, i.e. the effective utilisation of the time and energy available to them. Because of its integration in the production chain and its drive to secure its own existence, the organisate developes a considerable amount of dynamism.

The drive for efficiency and the involvement in the rhythm of the market also demand a certain order in the structure of the process. The process peculiar to the organisate is the process of "conversion". It is distinguished by successive qualitatively differing process stages. ROGERS (1962/83) also made out several stages in the acceptance of an innovation in a company (knowledge - persuasion - decision - implementation - confirmation). We can proceed slightly more accurately. The process is hierarchically divided in two ways:

1) The process takes place vertically according to the system structure between the superior and the inferior environment, and it is here that the division into board of directors and workers, i.e. system and element horizons, finds its true purpose. As with flow equilibrium (see section 2.3.2), four bonding levels appear (input and acceptance in the system horizon and input and acceptance in the element horizon). The stimulus or demand (e.g. for a certain quantity of a new type of cloth) comes from the superior environment i.e. the market. First of all, this information is adopted. The "adoption" concerns the preparatory time. Exact planning is necessary in order to avoid unnecessary waste of time and energy. The

information is processed in the organisate by passing it in a downward direction through every bonding level in the system (flow of information). At each of these bonding levels a task has to be resolved. These partial processes can therefore be termed task process stages or simply "task stages". Let us attempt to describe these processes at a more general level using the example of the textile mill and its departments (see fig. 15).

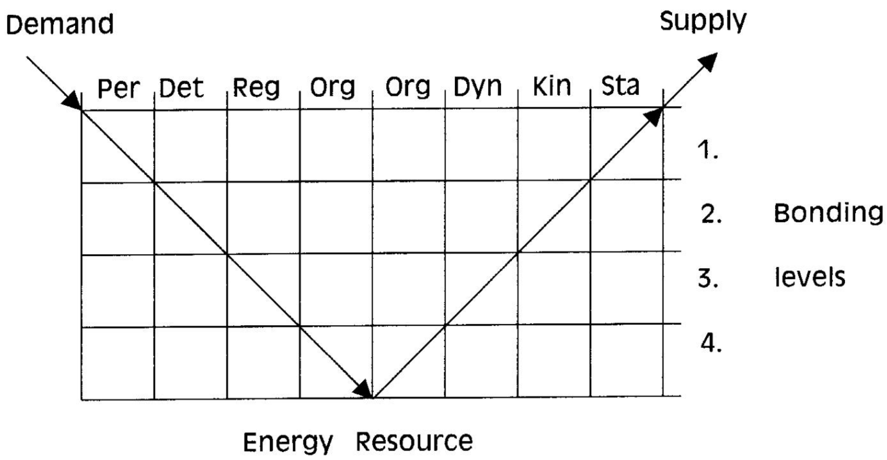


Fig. 15:
Course of the induction process through the bonding levels.
At the perception stage, the flow of information (demand for products) is received from the superior environment and then processed at the stages of determination, regulation, organisation, and passed to the inferior environment, the energy resource: "adoption". From here, the flow of energy again leads up to the superior environment. At the stages of organisation, dynamisation and kinetisation, the energy is processed to the demanded products: "production". The supply to the demanding superior environment (market) takes place at the stabilisation stage.
(Source: see "Notes on the figures").

1st bonding level: the demand is received from the superior environment, i.e. the market, in the form of information ("perception" as task). Carrier: the marketing department.
2nd bonding level: here it is evaluated and decided whether the stimulus to production should be accepted, and if so, to what extent (depending on the capacity of the company). "Determination" as task. Carrier: the board of directors.
3rd bonding level: depending on the decision taken, it is laid down who (workers) should carry out which particular job in the production process. The division into work groups is also possible ("regulation" as task). Carrier: the planning department, middle management, employees' representatives.
4th bonding level: the inferior environment is involved. Material and energy are ordered. In the meantime, the suppliers prepare the delivery of energy and raw materials ("organisation" as task, as part of adoption). Carrier: the purchasing department.

At the stage following "adoption" is the "production", the work is carried out according to the adopted information. This is the flow of energy and is passed upwards through the bonding levels. Here too, a number of task stages can be distinguished:
4th bonding level: material and energy are supplied from the inferior environment (supplier companies). (Once again, "organisation" as a task - this time as part of the production stage). Carrier: the purchasing department and stores administration.
3rd bonding level: the materials and energy are distributed to the workers (or work groups) and the action projects possibly prepared in accordance with the division of labour principle ("dynamisation" as task). Carrier: the stores administration and workers or possibly the work groups.
2nd bonding level: the workers assemble the (prepared) raw materials and manufacture the products ("kinetisation" as task). Carrier: the production department (machine shop).
1st bonding level: the products are offered to the demanding market for sale. This decides whether the products (and the system) can maintain their position ("stabilisation" as task). Carrier: the sales (marketing) department.

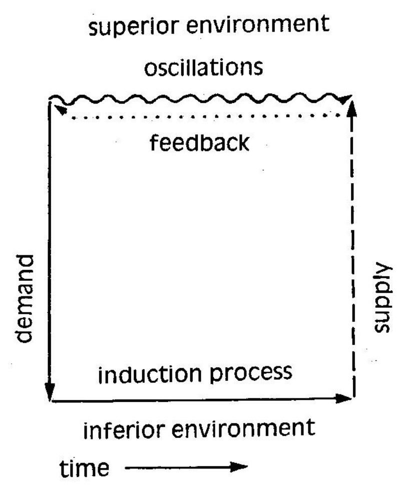


Fig. 16:
Feedback in the non-equilibrium system.
The induction process commences with the receipt of the demand and ends with the supply to the market (superior environment). The feedback takes place through comparison of the supply with the demand.

2) The conversion process does not only follow the vertical divisions of the system structure at the bonding levels. It is also divided up within itself in accordance with the process hierarchy. We are already familiar with "adoption" and

"production". These belong to the "main process" which includes a total of 4 stages. To adoption and production are added "reception" and "reproduction". Adoption and production serve the market ("induction process"), reception and reproduction the system itself ("reaction process"). The induction process as a whole ends at the stabilisation-task stage with the offering of the product on the market. Through feedback, it is determined whether the supply corresponds to the demand (see figs. 16 and 17). This also applies to the task stages. As at the main stages, at each task stage it is verified through feedback (and monitoring by management), whether the task has been satisfactorily carried out.

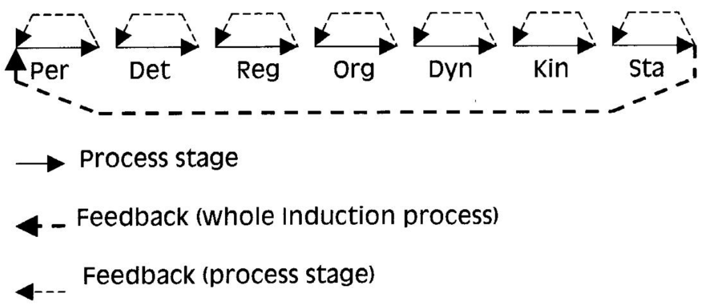


Fig. 17:
Feedback in the non-equilibrium system.
Not only the induction process as a whole, but also the individual stages are regulated by means of feedback. In addition however, the stages are controlled from the system as a whole.

If the process proves to be practicable, i.e. if the market is satisfied, the company is adapted to the new situation on the basis of experience and according to feedback at the stabilisation stage. This is (as already mentioned) the "reaction process". It means self-organisation. It is constructed in the same way as the induction process. First, there is the perception of the problems and planning ("reception"), then execution ("reproduction"). I.e. it travels as a flow of information in 4 task stages (perception ... organisation) downwards through the bonding levels (reception) and in 4 task stages (organisation ... stabilisation) upward through the bonding levels as a flow of energy (reproduction). For this purpose, the organisate creates an appropriate internal structure which allows it to carry out the tasks systematically and without any significant waste of time.

In all cases, the task stages (perception ... stabilisation) divide the main process to which they are assigned hierarchically. The 4 main-process stages each correspond to 4 task stages, thus resulting in a total of 16 task stages. In reality, the main stages adoption and production overlap one another in the organisation stage. This also applies to the main stages reception and reproduction with regard to time in the reaction process, which means that 7 stages remain. As the task processes of stabilisation in the induction process and perception in the reaction process also overlap, the result is a total of 13 task stages in the main process.

The organisate represents the persisting "non-equilibrium system" which is preserved and modified by the "conversion process". We are at the 4th level of complexity.

The superior flow-equilibrium system, i.e. the compartment of the market, is composed, as already mentioned (see section 2.3.2) of non-equilibrium systems, the organisates, which carry out the actual production. On the other hand the non-equilibrium systems receive the energy which they need for the conversion into products through inferior flow equilibrium systems. This energy, again, is made available by inferior non-equilibrium systems. In this way a production chain becomes recognizable with different levels which themselves consist of a number of non-equilibrium systems.

The non-equilibrium systems ensure that the vertical flow of information and energy expressed therein, is given a qualitatively precise form through the manufacture of products. In this way, noise is limited in the transfer of information, and dissipation in the transfer of energy. These hierarchies enable a self-regulation of the economy over several levels. Our economy would be inconceivable without these "mechanisms".

2.4.3. The model

The system is given form by the interactions with its environments. The greater the degree of complexity, the less information and energy are lost, but the greater the amount of structural influence withdrawn from the environment and included in the system. In our discussion of flow processes (see section 2.3.2) it was already indicated that the system incorporates a part of the environment, i.e. the energetic environment, and is in turn affected by the environment in form and arrangement. The system receives the stimulus from the superior environment and structures itself hierarchically. The flow of information can enter. Then the system stimulates the inferior environment so that the flow of energy can take place. Thus, 2 process trains exist (see also section 3.2.4):
1st process train: stimulus from the environment -> structuring of the system -> influence on the environment;

2nd process train: stimulus from the system -> structuring of the environment -> influence on the system.

This twofold formation tendency is also seen in the structuring of the conversion process resp. the non-equilibrium system. This creates a large number of relationships which have to be scrutinised more closely. To avoid losing our way, we can arrange the section into these 2 process trains:

2.4.3.1. First process train

The model in the frame of the process theory

In discussing the first, second and third level of complexity, we saw:
1. that new problems have to be solved at every level of complexity:
- with solida and simple movements, the transfer of energy is of primary importance,
- with equilibrium systems and movement projects, it is the differentiation of the sequence of a process in time, and
- with the flow-equilibrium systems and flow processes, it is principally the formation of a hierarchy in the system, in order to control the flows of energy.

We also saw:
2. that with each step from one level of complexity to the next higher level, these formerly acquired characteristics and abilities are also taken over.

This is also the case here. The organisates as non-equilibrium systems comprise a transfer of energy (see the first level of complexity, section 2.1.3), a division of time (see the second level of complexity, section 2.2.3), and an arrangement of the system into hierarchies (via bonding levels; see the third level of complexity, section 2.3.3). Thus process sequence and system structure converge. In this way it becomes possible for the partial processes (task process stages, see section 2.4.2) to join up in such a way that the flow of energy can proceed.

However, there is no effective linking of the processes until the necessary contacts are also made between the elements and with the systems of the environment as source of energy. It is obvious that the more the system closes up and the closer the sources are to the system, the more easily this can take place. This is achieved by another process. This process of concentration now has to be defined.

We have already discussed the long-range effect (see section 2.2.3) which can be described fairly well using Newton's Law of Gravity. Everything which seeks contact with a point of attraction moves radially towards it. At the centre, the density of the objects seeking contact (the elements) is very high and declines rapidly as we move outwards and then much more slowly towards the periphery. The process which produces this result, is termed the "elementary process".

First of all, let us assume that the attractive power of the centre is increased by new attractive stimuli being created. This also increases the long-range effect and the space requirement. Because small non-equilibrium systems generally have a low degree of attractive force and larger ones a higher degree of attractive force and long-range. To describe this, we assume that new attractive elements are taken into the initial location of a given volume of the non-equilibrium system. The density value increases. If the original density value is to be restored, the system has to be enlarged into the environment.

This happens in the 4 elementary process stages. They can be described by the following functions:

[12] $$N_n = N_{n-1} + \frac{K - N_{n-1}}{k}$$

At the 1st elementary process stage the element units requiring space are brought into the system. The density increases, i.e. intake of additional units N in the given volume of system K. The formula for negative exponential increase can be used:

(N = number of spatial units; n = temporal steps; k = constant; K = upper limit).

- At the 2nd elementary process stage it is necessary to calculate how the increased density is dosed and transformed into an elevated number of steps, with which the elements can be brought into a new space. In this way, the possible enlargement of the system and the field of long-range effect is prepared. The formula for a linear development

[13] $$N_n = N_{n-1} + k$$

(N_n = number of steps at the moment n; k = constant).

- This converted value is (in the 3rd elementary process stage) the basis for the diffusion of the spatial elements into the spatial environment. The formula for a positive exponential development

[14] $$N_n = N_{n-1} * k$$

(N = number of the diffused spatial units; n = temporal steps; k = constant, which represents the increase at each step).

- Until now it has been assumed that all elements require the same space. Now, at the 4th spatial process stage, the elements require different amounts of space. This varying requirement depends on the distance from the centre. In the immediate vicinity of the centre, the least space is available. Further outwards the available space increases. The exponent a states the (geometrical) dimensionality of the space, into which the system expands. For a homogeneous surface a = 1. For a (geometrically) three-dimensionally shaped space a = 2 (according to Newton's Law of Gravity):

[15] $$N_n = (N_{n-1})^a * k$$

(N = Number of the diffused spatial units; n = temporal steps; k = constant, ascend factor).

It is, however, also possible to interpret the formula in such a way that exponent a reflects the intensity of the long-range effect from a centre to its surroundings, i.e. the intensity of the readiness to adopt. If the value a is smaller, i.e. only a little more than 1, the acceptance is small, the long-range effect is small. If the value a, however, is distinctly greater than 1, this means that the centre has a greater effect on its surroundings.

In this way the system concentrates itself, takes on a compact shape and builds up its sphere of influence (its area of long-range effect), through which it interacts with the other systems. It is a spatial influence of a general nature, as expressed for example in a catchment area for workers. As yet, no material differentiation in the sphere of influence is apparent (see the elementary processes, which originate from the environment by way of contrast, section 2.4.3.2).

This process coming from inside, from the system, which shapes the spatial environment, is not strictly controlled outside the system itself, because the elements seeking contact around the centre must themselves decide how close to the centre they wish to be. A commuter for example, also has other priorities (see section 2.2.4.2). Thus, this process governs itself, there is no central control. Accordingly, a feedback process takes place at the end of each partial process.

Comparison with the model of Artificial Society:

The above remarks on the first train of processes show that, in the space-shaping processes, we are dealing with the first signs of spatial self-organisation. Let us now look at these processes more closely. The transition from the sphere of the flow-equilibrium system to that of the non-equilibrium system has been given special attention in the field of (chaos and) complexity research. However, it is not easy to compare correctly the results achieved in these areas of research with those of our theory, as the approaches are quite different. The method promising most success would be with reference to diffusion research (see section 2.3.2, 2.3.4).

As an example, we used the spread of innovations and colonisation (see sections 2.3.2, 2.3.4.2). An essential condition for each of these diffusion processes is
1. that the stimulus comes from the superior environment, i.e. from the market, which indicates that there is a greater requirement for products (e.g. woven goods, foodstuffs) attributable to a rise in population,
2. that the system as a whole is ready and able to adjust accordingly (i.e. to diffuse an innovation or bring more land under cultivation),
3. that the elements are able, after adoption, to put the innovation into practice or to colonise the land, and
4. that the inferior environment provides sufficient energy resources.

The process of diffusion is controlled not only from below, i.e. from the inferior environment and the supply of energy, but also from above, from the superior environment. It must be remembered that each flow-equilibrium system is located in a vertical flow of information and energy (e.g. product or food chain) and both have to be controlled vertically by the system and its elements (see sections 2.3.2, 2.3.3).

During the diffusion process, the elements are stressed to the limit of their capacity to fulfil the higher requirements. It may now happen that the demand from the superior environment exceeds the supply with the result that the system (with its elements and the inferior environment supplying energy to them) is unable to meet the requirement. The elements now loosen their links to the system and re-align themselves, because they can only exist if they remain in the flow of energy. Thus, they tend to move towards the parts of the inferior environment which provide sufficient energy. This is the pre-condition for the alignment of the elements with centres in accordance with the long-range effect described above.

From this point, it is possible to make use of the Artificial-Society model (in the context of complexity research). It is centred on the individual elements and attempts to understand highly complex structures "from the bottom up" and to simulate them (EPSTEIN & AXTELL 1996). The "agents" as the elements act in a spatial environment according to certain rules.

What is new, is the fact that each of them is equipped with certain characteristics and rules of conduct (e.g. sex, sight, metabolic rate, individual economic preferences, affluence, cultural identity, health). Thus, in addition to the dependence on the inferior environment ("landscape"), we also have dependence on the horizontal neighbouring environment. To be more precise:

The "landscape" appears as a grid over which the resources (e.g. foodstuffs) are distributed measurably as with the cellular automata. In this way, the operations can be expressed by rules which describe the behaviour of the agents and the reactions of the environment. The agents can interact indirectly with the environment via a communications network whose spatial configuration may change in the course of time. In this way, the agent is bound to his environment (agent-environment rules). Besides this, there are rules which govern the relationships between the agents, e.g. in cases of conflict or commercial activity (agent-agent rules). Moreover, every locality in the landscape may be linked to its neighbours through rules. Thus, the rate of the renewal of resources in one place may be a function of the quantity of resources in the neighbouring locality (environment-environment rules).

In the simulation, it is possible to see how macroscopic patterns form, e.g. there are more or less distinct concentrations of agents with certain features, or currents begin to form. The patterns change or become more stable. According to the interpretation of the authors wealth or poverty accumulate in certain places, social relationships come into being between neighbours or friends, co-operation and trading relations develop and diseases also spread. The simulation processes are regarded as activities and processes which are more or less typical of human society.

The method of simulation of patterns has also proved its effectiveness in other ways. New results continue to be achieved in widely varying areas of research. However, it is still not possible to achieve "artificial societies" in this way. Human society forms populations which are distinct from one another. In these, production takes place, flows of energy and are channeled and linked with one another to fulfil practical purposes. These groupings, non-equilibrium systems, organise the time at their disposal (process sequences) and shape their space themselves. Only they can supply energy to the superior environment more rapidly and more precisely because they produce products which make the flow of energy more precise and more effective, thereby reducing the dissipation of energy. But with the help of the model of the artificial societies, it can still be ensured that the agents reach the most favourable position in the landscape, i.e. the inferior environment. This is the pre-condition for the actual emergent processes which lead to the formation of populations.

Besides control from the bottom up, an accurate model of the processes required to form an artificial society must also take account of control from the top down. This is described below.

2.4.3.2. Second process train

In the last chapter we explained, how the non-equilibrium system and its environment receives spatial order developed from within. Now we will show, that not only the (supply of and demand for) energy, as with the flow-equilibrium system, is received from outside, from the environment, but that time is also incorporated into the system. This makes possible a process which is also thematically differentiated and which brings about the actual conversion characteristic of a non-equilibrium system (c.f. the movement project of the second level of complexity which is only structurally divided; see section 2.2.3). The course of this process is strictly controlled through a hierarchy. Four process levels can be distinguished, in which the processes and movements are ordered:
1st process level: The "main process" (see section 2.4.2) controlling the flow of energy and information of the non-equilibrium system, with its 4 stages of adoption and production (market-oriented induction process), reception and reproduction (self-organising reaction process of the system), represents the highest-ranking process. This process guides the flow of energy (to the demanding superior environment or into the system).
2nd process level: The time-differentiating "task processes" (see section 2.4.2) with their 16 stages (or 13 stages through overlapping) are subordinated to it.
3rd process level: Subordinate to these, the "control processes" fit the elements into the hierarchical structure of the bonding levels.
4th process level: These in turn are shaped in detail by the space-differentiating "elementary processes".

Main, task, control and elementary processes consist of 4 stages each. Each stage of the superior processes contains one subordinate process which itself consists of 4 stages (cf. fig. 18). The number of processes and stages therefore increases exponentially from the 1st to the 4th process level, i.e. (4+16+64+256=) 340 process stages altogether (but only 20 different formulae).

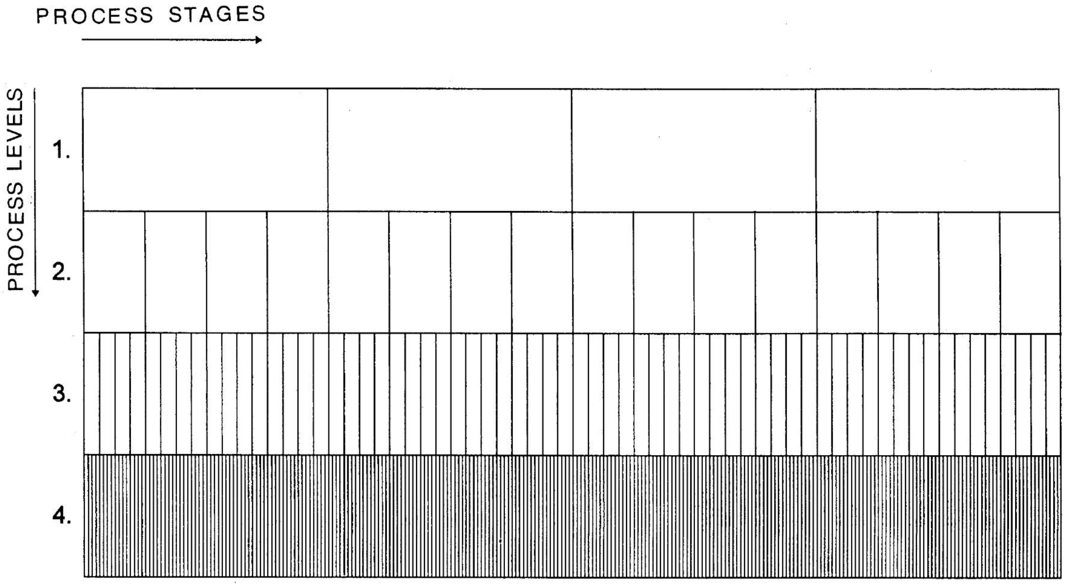


Fig. 18:
Hierarchy of the processes in the overall non-equilibrium system.
It is apparent that the process sequence is divided into 4 process levels, where the inferior processes in each case, each with four stages, are assigned to one stage of the superior process. Thus, the entire process sequence includes 4 + 16 + 64 + 256 = 340 stages.

Here, all the process stages have to be assigned codes to avoid confusion. The position of the processes can be defined in a table by means of letter combinations (see fig. 19). The different 4 stages or partial processes receive the letters S, T, U, and V. The 4 process levels are indicated by the number of these letters. Thus, 1 letter indicates the 1st process level (main process), 2 letters the 2nd process level (task process), 3 letters the 3rd process level (control process), and 4 letters the 4th process level (elementary process).

S, T, U, V: Main process (1st process level):

The main processes with their 4 "main process stages" (or in abbreviated form: "main stages") represent the 1st process level. They have to arrange the information and energy flow (from and into the environment, from and into the system), i.e. the sequence of the processes in the whole system.

For a system based on the division of labor (i.e. a non-equilibrium system), the time structure is decisive. The flow of information according to the demand and the flow of energy for the supply take place after one another. The conversion of

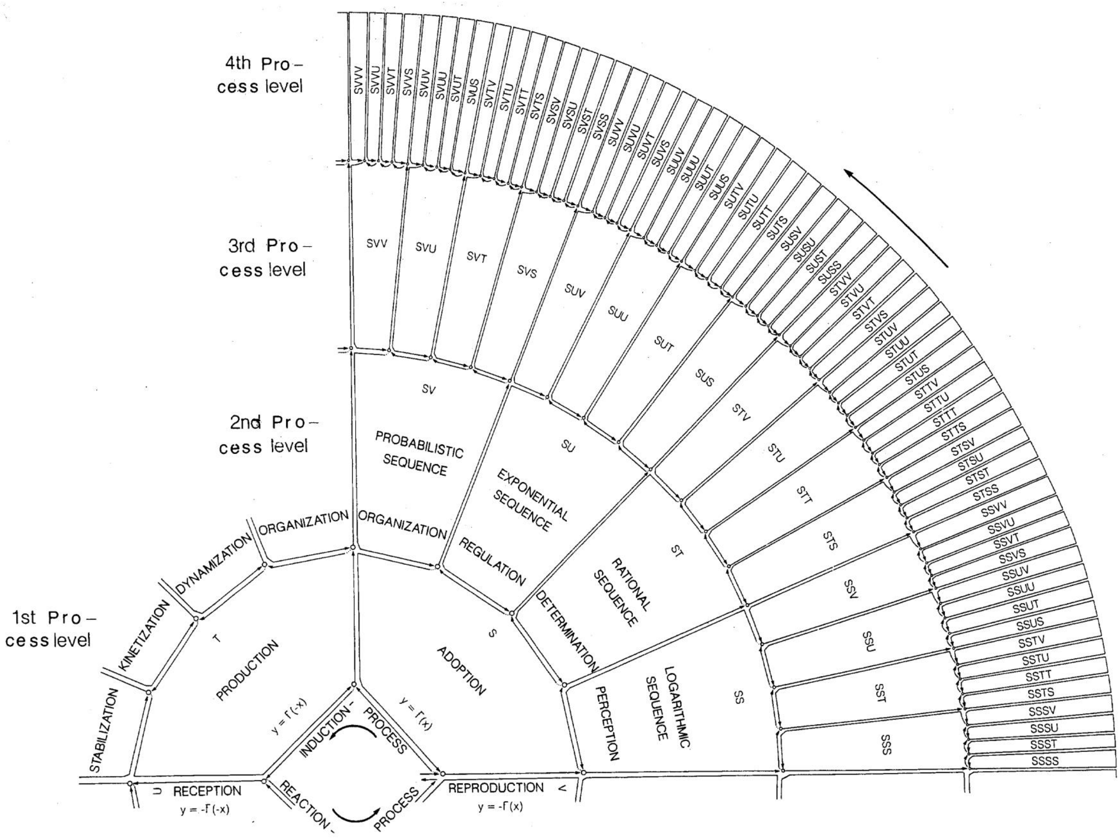


Fig. 19:
Hierarchy of the processes in the non-equilibrium system at the main stage of "adoption".
At the input (in the inside of the diagram) the stimulus takes place, i.e. the demand is entered. Initially, the process leads down through the four levels of the main process (adoption stage), task process (perception stage), control process (1st stage) and elementary process (1st stage), i.e. outwards in the diagram, where it passes through the four elementary stages belonging to the first control stage, and then works up from there to the second control stage. Then there is another descent to the elementary stages etc. until the four control stages have been passed. Only then does the process move up again to the second task stage (determination).
(Source: see "Notes on the figures").

information and energy (from raw material to the finished product) takes time, and when the required product has arrived on the market in the required quantity, the demand may have changed. Thus oscillations may result, i.e. a circular process (see flow processes, sections 2.3.2, 2.3.4.2).

The oscillations determine the time budget and the internal sequence of procedures in time. They can be linked with the 4 main stages and presented in a system of coordinates (see fig. 20).

Adoption (S): The demand from the market as the superior environment is represented in the y-positive half of the coordinate system. At the beginning, the demand is taken upon the system and therefore increases. The energy is demanded

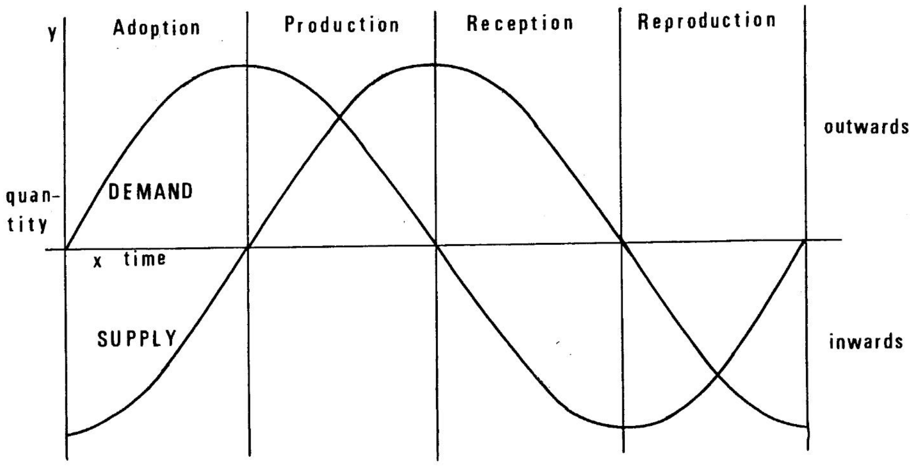


Fig. 20:
The main stages (adoption, production, reception, and reproduction) in the interaction of demand and supply.
Both stimulate each other mutually, oscillations occur which impose their rhythm on the internal process sequence. In this way, the non-equilibrium system receives its periodic division. See also fig. 8.
(Source: see "Notes on the figures").

from the inferior environment. [In the organisate, the demand for a certain quantity of a certain product is received from the superior environment, i.e. the market, and processed in the system. Adoption stimulates the processes within the company (task, control and elementary stages).]

Production (T): The supply curve is shown in the y-positive half. The production for the market increases, while the demand decreases to the same extent. The demand and supply curves intersect one another. [The production of the organisate itself takes place in accordance with the information specified, but also on the basis of the energy etc. contributed by the inferior environment (e.g. its suppliers). This main stage includes processing of the raw materials up to the supply to the market.]

As already described above (see section 2.4.2), not only the market has to be supplied with energy (in the form of products). The system itself must also receive energy, otherwise it will decay. So we can distinguish between the "induction process" which satisfies the requirements of the market, and the "reaction process" which affects the system itself, i.e. the system adapts itself to the new conditions. This is self organisation. The system arranges its elements in a way which is most favourable for production, i.e. the flow of energy. Here, too, information precedes energy flow, i.e. it must first be established what has to be renewed before the renewal process can begin:

Reception (U): The demand curve leads into the y-negative zone, stimulates the system to adapt itself. The supply curve begins to decline. This reflects the same development as for adoption but with a reversed situation. [An organisate must undergo a continuous process of renewal in accordance with the requirements of the market and for the purpose of saving energy. This is registered first of all as information, and planned accordingly.]

Reproduction (V): The demand curve moves into the y-negative zone towards the x-axis again. By contrast, the supply curve declines into the y-negative zone, i.e. the system itself is supplied with energy and is changed. Elements are increased in number with the result that this stage is comparable to that of production. [In the organisate, this is expressed in the actual maintenance and investment tasks - depending on the circumstances of the market and its own possibilities and intentions.]

The oscillations around a central point described above have an effect on the direction of the subordinate processes. The induction and reaction process are aligned towards one another on the level of the task processes, and in detail once again within adoption and production and reception and reproduction. Here, it becomes apparent that the contrary action discussed in the first level of complexity (symmetry, see section 2.1.3) also applies here. These oscillations can be described mathematically by the Lotka-Volterra equations (see section 2.3.3, no.11).

SS, ST...: Task processes (2nd process level):

The "task process stages" (or "task stages" for short) are located at the 2nd process level. Here, subordinate to the main processes, the processes are ordered according to the time sequence specified by oscillation (main process, see above) and in connection with the 3rd and 4th process levels (control and elementary processes, see below) performed.

The formulae describing the task stages were already presented in the discussion of equilibrium systems (see section 2.2.3. nos. 3 - 6). Here, in association with the remaining processes, they are functionals which dictate the types of calculation.

In the adoption process (S) the stimulation, i.e. the demand for certain products, has to be incorporated into the structure of the system. The higher the demand, the stronger the stimulus for the process as a whole. Thus, the perceived information has to be transformed and distributed according to the structure of the system, in a similar way to the energy itself later, during the production stage (T).

We will consider the task stages of the induction process more closely (see fig. 21):

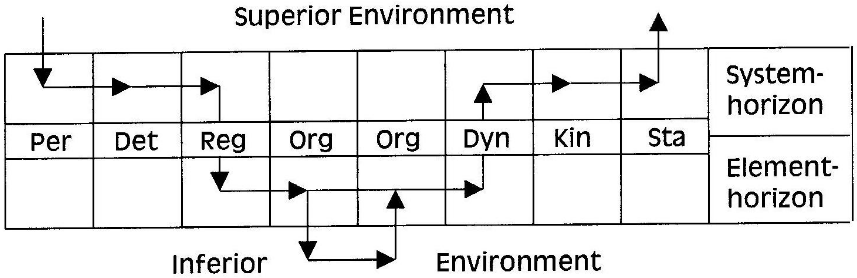


Fig. 21:
The course of the prozess sequence (induction process) in the system horizon and the element horizon of a non-equilibrium system.
Vertical arrows: Flow processes (information resp. energy flow), horizontal arrows: Changing and coupling processes.
Per = perception, Det = determination, Reg = regulation, Org = organisation, Dyn = dynamisation, Kin = kinetisation, Sta = stabilisation.
(Source: see "Notes on the figures").

SS (Arrangement of the stimulation strength, "perception"): The demand of the superior environment stimulates the system into activity, the system "perceives". The performance of the system demanded by the superior environment must be transformed into the system according to its size. We call the value which is dependent on the internal structure of the system, "stimulation strength". This is described by logarithmic functions (see 2nd level of complexity, section 2.2.3, formula no. 3):

ST (Adaptation of the stimulation to the system, "determination"): The system, however, cannot be stimulated at will. The value of the stimulation strength must be reduced, as some elements are already stimulated. The system determines the extent of the accepted stimulation. The result is a reduced value. This is described by rational functions (see 2nd level of complexity, section 2.2.3, formula no. 4):

SU (control, diffusion of the stimulation into the number of elements, "regulation"): The relative increase of the stimulation strength of the system has to "regulate" the internal distribution of the limited stimulation among the number of elements. An attempt is made to achieve an internal flow equilibrium between the stimulation which is supplied from the system horizon, and the stimulation which is demanded from the elements. The potential adopters become definite adopters, i.e. the demand for action is accepted by the elements step by step. This is described by exponential functions (see 2nd level of complexity, section 2.2.3, formula no. 5):

SV/TS (Demand for energy from the inferior environment, transition from the adopters to the potential producers, ordering of processes, "organisation"): As described, the adoption (S) prepares ("organises") the system to receive energy from the inferior environment as well as for production. In the production stage (T), the organisate converts energy and supplies the product to the market. The task of organisation in the adoption process (SV) also defines the beginning of the task of organisation in the production process (TS). Both tasks are dealt with in one stage. The number of adopters which become producers depends on how much energy can be received from the inferior environment. The transition from adopters to producers can therefore only be defined with a certain degree of probability. This is described by probabilistic functions (see 2nd level of complexity, section 2.2.3, formula no. 6):

TT (Distribution of energy from the inferior environment to the elements, "dynamisation"): In the meantime, the inferior environment has provided the energy for production and supplies it to the system. In this way the system is "dynamised". This in turn is described by exponential functions (as for SU, see above):

TU (Conversion of the energy to the products, "kinetisation"): The different individual energies or materials are combined to form new products (in accordance with the quantity specification established at stage ST, determination). This is the actual production. Rational functions describe this (as with ST, see above).

TV (Supply of the finished products, "stabilisation"): The products are offered to the (demanding) superior environment. A feedback process determines whether the result is satisfactory. In this way, the system is "stabilised". Perhaps the demand has changed in the meantime. At the same time, a new induction process can begin (perception). This is described by logarithmic functions (as for SS, see above).

Thus the conversion (induction process) consists of a number of task processes in a specific sequence and is therefore irreversible. Through its specific shape and size, the product contains the information of the stages SS ... SV as well as the energy of the stages TS ... TV.

With the stabilisation phase of the induction process the reaction process (reception U and reproduction V) however begins. In the reaction process, corresponding activities regulate the optimising of the system itself. This is where the actual "self organisation", typical of non-equilibrium systems, takes place (see section 2.4.2). The system learns . These processes are structured to the same extent as the induction process. It is not necessary to pursue this in detail here.

As the stabilisation stage (TV) of the induction process is already taking place simultaneously with the perception stage (US) of the reaction process, the process sequences of 7 and 13 (instead of 8 and 16) links (or task stages) containing induction and reaction process are created.

SSS, SST....: Control processes (3rd process level):

Within the different task stages, the processes (flow of information and energy) from the superior and inferior environments have to be linked to the system and the elements. This happens - at the 3rd process level. [For the organisate, the superior environment is the demanding market, the inferior environment the supplier providing the energy and raw material. The elements are the non-divisible working units or employees.]

In the discussion of the first set of processes above (section 2.4.2, 2.4.3.1), we explained that the task processes cross the bonding levels between the superior and inferior environment (as with the flow-equilibrium system; see section 2.3.3) and are thereby ordered. Here, (in the second set of processes in the non-equilibrium system) the bonding levels are in turn ordered by the task processes. In this way, the system receives its control structure. The process consists (depending on the succession of bonding levels) of 4 stages, in which the stimuli (demand) enter the system, bonding level for bonding level. Thus, the elements are bound progressively more tightly ("control process stages" or "control stages" for short).

In this way, precise control of the course of the processes in all main and task stages becomes possible. We will consider the adoption process (S), i.e. the information flow, more closely. It is not difficult, to extend the model to the three other main stages.

1st control stage (1st bonding level): The system defines itself exclusively as a quantity of elements. These are by themselves, without restriction by a specified system.
2nd control stage (2nd bonding level): The elements have their position (and function) in the system, are integrated in it,

and appear as components in a limited system. Each of the elements strives individually to achieve an equilibrium in the system as a whole.
3rd control stage (3rd bonding level): The elements are dependent on the stimulation by the system horizon, but they are also non-equlibrium systems on their own (in a hierarchically inferior position) which take their place in the system. They themselves strive actively to obtain a place in the flow of information. Thus, the demands of the system (as system horizon, see sections 2.2.2, 2.3.2) are opposed to those of the elements.
4th control stage (4th bonding level): The system makes contact with the inferior environment, in order to receive energy according to the stimulation. [In previous studies, e.g. 1997, I assumed that the interaction of system and element horizon is dealt with at this stage. However, it is already the subject of the 3rd control stage].

Thus, in the control stages, the bonding levels again appear, but no longer only to organise the system vertically as in flow-equilibrium systems, but to clarify the differing integration of the elements, as the elements are dependent on their incorporation in the flow of information and energy.

These 4 steps must be gone through within each task stage, and the values are transferred in each case. Besides this, in every control stage, the values from the same stage in the previous task stage are taken in, e.g. from STS the values from SSS etc. Thus, each process stage is doubly involved.

Perception, control stages SSS, SST, SSU, and SSV:

In this task stage, the demand from the superior environment is entered into the system, inasmuch as the size (according to the constellation of elements, see above) permits. The greater the demand, the greater the stimulus. In this way, the extent to which the system would be stimulated is reflected.

SSS (1st control stage): The stimulus from the superior environment is entered into the system, which defines itself globally by the number of undifferentiated elements (see 2nd level of complexity, section 2.2.3, formula no. 3).

SST (2nd control stage): The stimulus is conveyed to the system in a limited number of elements. The number of elements demanded (characteristic *A*) is shown in contrast to the number of the existing elements (characteristic *B*). The two categories *i* (*i = A, B*) attached to these each consist of a certain number of elements. The probability of the elements appearing depends on this.

The probability *p(A) = 1 - p(B)* applies. If the elements of both categories occur with the same frequency, i.e. if *p(A) = p(B)*, the probability that a representative of category *A* or *B* will occur is 0.5. That means that the number of demanded elements corresponds to the number of existing elements. The stimulation is then highest. If however *p(A)* = 0, then *p(B)* = 1 (or if *p(B)* = 0, then *p(A)* = 1). Within the meaning of the theory of information, the surprise or information content is *I* = 0. Then there is no flow of information and no stimulus.

The formula for the average stimulation strength *I* of the system which is formed by both categories *i = A* and *i = B* is

[16] $$I = \sum_{i=A}^{i=B} p_i * ld(\frac{1}{p_i}) \quad bits$$

This is the formula of the "entropy" (here with 2 categories only) as intended by the information theory (SHANNON and WEAVER 1949/76). In the physical sense, it is negative entropy. We will therefore call it negentropy.

SSU (3rd control stage): The stimulus is put into the elements, which, in their turn, desire the stimulus to assure their own existence. The stimulus is represented by the system horizon and the elements requiring the stimulus are represented by the element horizon. The elements with their own dynamics also come to the fore. [System horizon and element horizon assume, so to speak, the function of employers and employees within the organisate. The employer must ensure that sufficient demand enters the organisate so that the employees can be supplied with work they demand for their own living.]

Thus, the grouping of SST is again sub-divided. Information flows in both directions. The system horizon offers potential work (supplied demand, characteristic *A*), divided into *i* categories (*i* = 1, ..., *m*). The elements ask for a certain amount of work (demanded demand, characteristic *B*), divided into *j* categories (j = 1, ..., *n*). The degree of correspondence between work demanded and work supplied is required. Here a bivariate investigation (according to the information theory) is needed, because the objects are measured on 2 scales. The frequency distribution may be shown in a cross table, where the lines represent characteristic *A* (categories *i*), and the columns characteristic *B* (categories *j*). We call the probabilities of the product tables p_{ij}. We then obtain the following marginal distributions:

$$p_i = \sum_{j=1}^{j=n} p_{ij} \quad \text{resp.} \quad p_j = \sum_{i=1}^{i=m} p_{ij}$$

Then the demanded negentropy has the information content (SCHWARZ 1981, pp. 43.):

[17] $$I = \sum_{i=1}^{i=m} \sum_{j=1}^{j=n} p_{ij} * ld \frac{1}{p_{ij}} \quad bits$$

From this is derived the transinformation which reflects the degree of connection between characteristics *A* and *B* .

SSV (4th control stage): The stimulus is also passed to the inferior environment, which must supply the energy to carry out the production (in the main process stage T, see above). The demand, i.e. the information is passed from the system to the inferior environment. According to the information theory, we may regard the system as a transmitter or source (characteristic *A*) of the stimulus (or demand for energy), and the inferior environment as receiver or drain of the stimulus (characteristic *B*). To each of the 2 characteristics *A* and *B* are assigned categories (i = 1, ..., m; j = 1, ..., n). The transmitted information will be received with a certain probability. So here the source negentropy I_S is confronted by the drain negentropy I_D. These can be represented in a table as lines and columns (= asymmetric channel as per information theory; SCHWARZ 1981, pp 58.). It is necessary to take account of "noise" in the transmission process. A certain part of the transmitted information does not pass from the source to the drain (equivocation). On the other hand, information which has not been transmitted may arrive at the drain from outside (irrelevance). The negentropy consists of the source negentropy and the irrelevance, or of the drain negentropy and the equivocation. The information content is expressed in the following formula for the average source and drain negentropy (I_S resp. I_D)

$$I_S = \sum_i p_i * ld \frac{1}{p_i} \quad bits \qquad \text{or} \qquad I_D = \sum_j p_j * ld \frac{1}{p_j} \quad bits$$

This produces the negentropy I_V, which describes the whole information content:

[18] $$I_v = \sum_i \sum_j p_{ij} * ld \frac{1}{p_{ij}} \quad bits$$

(Indices for the source negentropy i = 1...m, for the drain negentropy j = 1...n; probability of the product categories p_{ij}).

From this, the transinformation which reflects the extent of the connection between characteristics *A* and *B* can be derived.

Determination, control stages STS, STT, STU, and STV:

How much stimulation strength (information content, see above) the elements (as the potential adopters) can still accept is determined in this task stage (see ST, above). The strength of the stimulus is reduced by the amount by which the system is already bound.

STS (1st control stage): The decision is accepted in the system, which defines itself globally as the quantity of undifferentiated elements (see 2nd level of complexity, section 2.2.3, formula no. 4).

STT (2nd control stage): The decision is also based on the capacity specified by the system, i.e. the positions in the system (and functions for the elements).

The stimulation is distributed to a limited number of elements *c*. The ability of the system to be stimulated is *d*, and *w* is the number of elements loaded (i.e. already stimulated). Thus, the term (*c* - *w*) indicates the part of the elements which is not yet stimulated, and thus still capable of being stimulated. The smaller the number w, the more stimulation can be accepted. If is *w* = 0, then *d* = 1. If, on the other hand, *w* = *c,* all the elements are already stimulated. The loadability of the system, or its ability to be stimulated, decreases linearly (*w* is the x-variable).

[19] $$d = \frac{c - w}{c} = 1 - \frac{w}{c}$$

STU (3rd control stage): The decision takes into account the fact that the elements for their part also require stimulus.

The relative ability of the system to accept stimulation does not decrease linearly as the stimulation enters (as was the case with STT). Instead, the graph describes a curve which arches upwards. We must distinguish between 2 different levels: the level of the system as a whole (the system horizon) and the level of the elements (element horizon). Both the (demand supplying) system as a whole on the one hand, and the (demand demanding) single elements on the other hand can each be loaded relatively by stimulation. The system as a whole reacts in the same way as the STT system. The total of all elements is *c*, which is diminished by those elements *w*, which are stimulated already, i.e. *c* - *w*. If we assume that the system consists of *c* = 10 elements, the initial value is *d* = 1 (when the system is not yet stimulated). Thus at the 1st step we subtract 1/10 from 10/10, so that 9/10 remain. This yields *d = 1 - w/c*. This is the 1st term. Now, we must also consider that each element, i.e. 1/10 of the system, can be stimulated further in the same way as the system as a whole. Thus, 1/10 of 9/10 must be added, i.e. (9/10)*(1/10). As the 2nd term, *(1-w/c)*(w/c)* must be added. Thus, the actual ability to accept stimulation is

[20] $$d = 1 - \frac{w^2}{c^2}$$

(*w* = stimulated, *c* = all potential adopters)

STV (4th control stage): The decision is also communicated to the inferior environment, which has to supply the required energy. The whole system is now integrated in the flow of information.

The system *A* and the inferior environment *B* influence one-another in their development. In contrast to the 3rd control stage (STU), a mean value is sought here because of the fluctuations (see below, SUV). The value of *c* therefore indicates the average number of all elements and *d* the average ability of the system to be stimulated. If *d* = 1, the system is quite open for stimulation. We return to the formula STT. If the inferior environment *B* gains stimulation, the number of the elements which can still be stimulated (i.e. which are loadable), decreases successively. I.e. it is possible for the inferior environment *B* to accept an average of *(c-w)/c* stimulation per element. The system *A* gives stimulation accordingly. In this case, *(c+w)/c* applies. The same applies, in reverse, if the stimulation travels from *B* to *A*. The values *c* (mean number of all elements) or *w* (number of elements already stimulated) are equal in both cases, because both system *A* and inferior environment *B*, relate to one another. As these are average percentage rates of change, we have to take the geometrical mean:

[21] $$d = \pm\sqrt{1 - \frac{w^2}{c^2}}$$

Regulation, control stages SUS, SUT, SUU, and SUV:

At this task stage the reduced stimulation (see above) is diffused into the bulk of the potential adopters (see task stage SU, above). The potential adopters become definite adopters. [The direction of the organisate involves the employees in the decision-making process. The remaining demand is finally accepted by the employees.]

SUS (1st control stage): The system (as undifferentiated quantity of the elements) adopts the stimulus (see 2nd level of complexity, section 2.2.3, formula no. 5 or 3nd level of complexity, section 2.3.3, formula no. 7).

SUT (2nd control stage): The system (under consideration of the stated capacity) adopts the stimulus. The diffusion of the stimulation into the quantity of elements of the limited system is performed (see 3rd level of complexity, section 2.3.3, formula no. 9: Logistic equation).

SUU (3rd control stage): The elements (as subordinate non-equilibrium systems) actively demanding the stimulus adopt the stimulus (see 3rd level of complexity, section 2.3.3, formula no. 10).

SUV (4th control stage): The inferior environment is "instructed" to supply the energy. Thus the entire system is in the flow of information from the superior to the inferior environment (oscillations; see 3rd level of complexity, section 2.3.3, formula no. 11: Lotka-Volterra-equations).

Organisation, control stages SVS, SVT, SVU, and SVV:

At this task stage (SV, see above) another reduction in the strength of the stimulus takes place. Here, adopters become potential producers, but only those for whom the energy and material basis from the inferior environment is secured. The production stage (T) begins simultaneously. The transition in the main process from adoption (S) to production (T) in the various arrangements of the elements is required. [The inferior environment as the supplier may have accepted the order, but can perhaps supply only a part of the required energy or raw material. The right conditions for production are created when the energy (raw material) are secured.]

SVS (1st control stage): The transition from adoption to production takes place first in the system, which defines itself only as the quantity of undifferentiated elements (see 2nd level of complexity, section 2.2.3, formula no. 6).

SVT (2nd control stage): The transition takes place with the elements in their position (and function) in the system. The demanded and given elements have to be combined in a limited system. So 2 sequences are joined together in the same way as a game with 2 identical dices. With each cast, a pair of numbers results: (1,1), (1,2), ... (z,z). The sum x_i can be at least the number 2 and at most the number $z+z$ (with standard dices, 12 spots). The result is that the random variables X_1, X_2 ... are arranged on the x-axis symmetrically to a centre x =

m, the points located symmetrically to this value (*m + k, m - k*) have the same probability *P*, thus

P(X = m + k) = P(X = m - k) for *k* = 0, 1 ... *m* - 2.

This results in the probability distribution:

[22] $$f(x) = P(X = x) = \frac{x_z - |x_z + 1 - x|}{x_z^{\,2}}$$

SVU (3rd control stage): The elements demand to be involved in the production process. The system horizon is opposed to the elements. Thus there is an attempt to achieve an internal flow equilibrium between the stimulation which is supplied from the system as a whole, and the stimulation which is demanded from the elements.

The well-known binomial distribution is applied. It describes an internal equilibrium between the work which is supplied from the system horizon, and the work which is demanded from the elements. The aim is the greatest collective profit. There are fluctuations in detail, but around a constant average value (expected value). The probability that a demanded element appears as part of the system horizon (event *E*) is taken as *p*. The probability that a demanding working person appears from the group of elements is taken as 1-*p.* For *x* stimulating elements and *n-x* elements to be stimulated, the result is

$$\binom{n}{x} = \frac{n!}{x!(n-x)!}$$

different permutations. Thus, the required probability distribution is

[23] $$f(x) = P(X = x) = \binom{n}{x} * p^x * (1-p)^{n-x}$$

(*x* = 0, 1....*n*).

If we enter the values *x* at the abscissa, and at the ordinate the values of the attached distribution function *F(x),* an S-shaped curve is the result.

SVV (4th control stage): Through the contacts with the inferior environment, the system becomes a unit which is located in the flow of information in a position of transition to the production stage.

The adopters of the system *A* and those of the inferior environment *B* will, with a certain degree of probability, become potential producers. Due to the oscillations (see above, SUV), varying numbers of these will, with a certain degree of probability, appear in the total number of elements involved. The question now to be answered is that of the discrete two-dimensional distribution (variables *X*, *Y*) at each moment of the oscillations. In the sense intended by the theory of probability, *A* and *B* are independent of one another. This describes the multi-nomial distribution (FISZ 1976). In a sequence of *n* single contacts, the adopters (of the system) *A* transmitting a demand for elements exactly *x* times (event *A*, random variable *X*) on the one hand, and the adopters (of the inferior environment) *B* receiving a demand for elements exactly *y* times (event *B*, random variable *Y*) on the other hand, become potential producers. The corresponding probabilities are $p_x + p_y$, if we assume $p_x + p_y + p_{n-x-y} = 1$. From *x, y* and *n-x-y* elements there are

$$\frac{n!}{x!\,y!(n-x-y)!}$$

permutations. So the probability function is

[24]
$$f(x,y) = P(X = x; Y = y) = \frac{n!}{x!\,y!(n-x-y)!} * p_x{}^x * p_y{}^y * (1 - p_x - p_y)^{n-x-y}$$

Graphically, the multi-nomial distribution has a bell-shaped form. By coupling its changing values with the oscillations (Lotka-Volterra equation, see above SUV), the frequency maximum describes one circle per oscillation wave. Perhaps this is one way of describing the tangential course of the rotation (see section 2.3.4.2).

SSSS, SSST...Elementary processes (4th process level):

When dealing with the first train of processes in the non-equilibrium system (see section 2.4.3.1), we saw that the system as a whole is compact in form and affects its environment spatially (long-range effect). There now follows a similar process in the second train of processes at the 4th of the lowest process level. Non-equilibrium systems require space internally and externally for their processes.

This process orders the system and its surrounding area according to thematic and structural considerations in line with the task and control-process stages. The space requirement therefore has to be fixed for each of the 16 stages of the control process (divided up according to task) in the adoption stage (S). A spatial value is assigned to each of the resulting values in the different control stages. In this way, the various control stages of the conversion process receive their contours. [This also applies to the main stages of production (T), reception (U) and reproduction (V)].

On the one hand, the individual parts of the system (i.e. in our example of the textile mill, the materially specified departments) concentrate on the topes (see section 2.3.1). This gives the system its internal form. On the other hand, the parts of the system create their fields of influence. In these, other non-equilibrium systems (e.g. the organisates of the suppliers) are stimulated to produce.

These "elementary processes" of the second process train in the non-equilibrium system can be described mathematically in the same way as the corresponding elementary processes of the first set of processes (see section 2.4.3.1, formulae nos. 12 - 15).

In this way, non-equilibrium systems shape themselves and their thematically specified environments. This process is located at the 4^{th} process level.

2.4.4. Other examples

Put briefly, the result is that all the stages of the 4 process levels must be gone through one after the other. Adoption (S) is a multi-differentiated process. In this way, the conditions are fulfilled for the system to open the energy flow, i.e. receive energy for production (T) from the inferior environment and produce the demanded product. The example of a textile mill allows the internal course of the conversion process in a non-equilibrium system to be examined. Other examples follow below.

2.4.4.1. Social and technical non-equilibrium systems

All social systems organised on the basis of division of labour can be assigned to this level of complexity. In order to distinguish them from other kinds of social system, we may speak of social "populations". Populations are those social systems in which changes in society originate.

A farm:

An example quoted earlier (see section 2.3.4) is that of the farm. The transformation of raw materials into products is not as apparent here as in the case of the factory, but it is still present. The grain has to be separated from the ears by threshing, vegetables cleaned, hay dried, animal feed (e.g. for pigs) prepared, potatoes selected, various plants fermented in pits or bins etc.
On the farm, the following sequence applies:

- Perception (1st bonding level): it is perceived that a requirement for certain products exists on the part of the market (superior environment).
- Determination (2nd bonding level): a decision is taken to grow these products on the basis of division of labour.
- Regulation (3rd bonding level): planning is carried out, i.e. it is laid down how, when, and by which persons the work should be carried out.
- Organisation, part 1 (4th bonding level): the fields (inferior environment) on which the products are to be grown are prepared (fertilising, ploughing etc.).

This is the processing of demand (flow of information), adoption. Then follows the production, i.e. the work itself, always in contact with the inferior environment, i.e. the sowing of seed, removal of weeds, extermination of pests, harvest. Production takes place, i.e. the supply is created (flow of energy):

- Organisation, part 2 (4th bonding level): the seed is then sown in the fields.
- Dynamisation (3rd bonding level): the growing crop is tended by the workers, the soil loosened, weeds removed etc.
- Kinetisation (2nd bonding level): the crop is brought in and prepared for sale.
- Stabilisation (1st bonding level): the products are supplied to the market (superior environment) for sale.

City-umland-populations:

If the populations are held together only by interaction (as are, for example, the cultural populations; see section 2.5.3.3 and 2.5.3.4) they distribute themselves spatially according to the statistically normal distribution (see fig. 22). However, if the members are arranged around a centre, the principle of long-range effect applies (see section 2.2; see fig. 23). The population concentrates in the centre. A particularly good example of this is the city-umland-population.

Here, the spatial effects of the process sequence can be observed particularly well. The town, with a certain central position (in Germany "Oberzentrum"; KLUCZKA 1970) concentrates specific functions within itself and engages in exchange with the mainly rural areas surrounding it. This type of population is heavily affected by traffic. In the hierarchy of the populations, the optimisation of traffic is the purpose it fulfills (see section 2.5.3.3). This is also reflected in the assignment of the concrete utilisation activities involved in

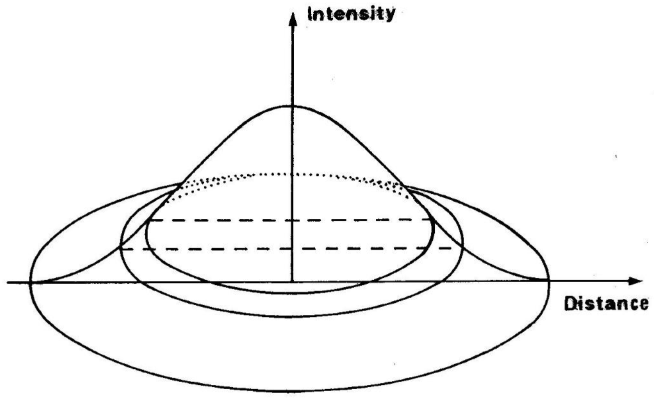


Fig. 22:
Spatial distribution of a group of people interacting with one another (population).
Density values (intensity) correspond to the statistical three-dimensional standard distribution.
(Source: see "Notes on the figures").

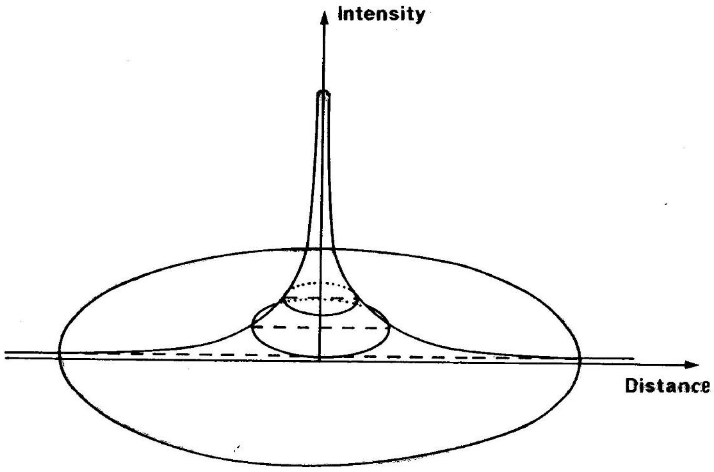


Fig. 23:
Spatial distribution of a group of people oriented towards a centre (initial location). Example: city-umland population.
The day and night population (i.e. the working population and the population using central services, and the resident population) have been grouped together and averaged.
(Source: see "Notes on the figures").

the tasks of the process sequence (as I have shown in the case of the town of Saarbrücken; 1987. See figs. 24 a and 24 b). The central business district is moulded by the tasks which

serve in the processing of demand, i.e. the flow of information (adoption):
- Perception: The centre of the town is (from a geometrical point of view) the most accessible point, i.e. among other things because it is here that producers and consumers can come into contact with one another most easily. The retail trade forms a link between the two groups.
- Determination: This centre also attracts the organisates which are most important for making decisions in the economy, i.e. representative offices of companies, banks etc.
- Regulation: the public administration adjoins towards the outside. It supervises the good order and legality of activities, thereby forming a link between the system as a whole and its inhabitants.
- Organisation: The actual elements of the city-umland-system are the inhabitants. They consume. The workers also produce and live either from their work in the central business district or in the industrial areas around its periphery. It is here that those districts of the town and country population begin, which are engaged in the actual production:
- Dynamisation: Moving outward, places of high productivity and high energy consumption become more common, industrial plants, intensive agricultural units, market gardens etc.
- Kinetisation: Then come the large traffic facilities (railway shunting yards, airports, highway junctions, canal ports etc.). Here the communities are concentrated in which the commuters live, i.e. those population groups which are dependent on effective communications systems with the town.
- Stabilisation: The extensive outlying districts are occupied by agriculture and central places of lower rank. It is in the area of transition to the field of influence of the neighbouring city-umland-population, that the system stabilises.

The city-umland population is limited by the accessibility of the city. The commuters and the inhabitants of the surrounding area making use of the services provided by the town must be able to reach it, carry out their work or other business and return to their homes in the course of a single day, as is the case with the city-umland population of Saarbrücken in the Saarland. Very high-ranking centres (CHRISTALLER 1933) have other functions (e.g. Frankfurt am Main which possesses a big airport and is a centre of finance) which go well beyond those of the city-umland population. For a discussion of these further-reaching areas of influence, see section 2.5.3.4.

Since the 1970s, the picture has changed slightly. The private car has become the favoured means of transport of the commuting population at the expense of the previously predominating public forms of transport. Many of the inhabitants have moved into the country, thereby attaching these areas more closely to the centre, i.e. the town as employer and shopping centre. On the other hand, new shopping centres with large car parks have appeared close to the residential areas. These too have loosened the economic relations between the retail business, the trades and agriculture, because the cost of transport no longer

Fig. 24 a:

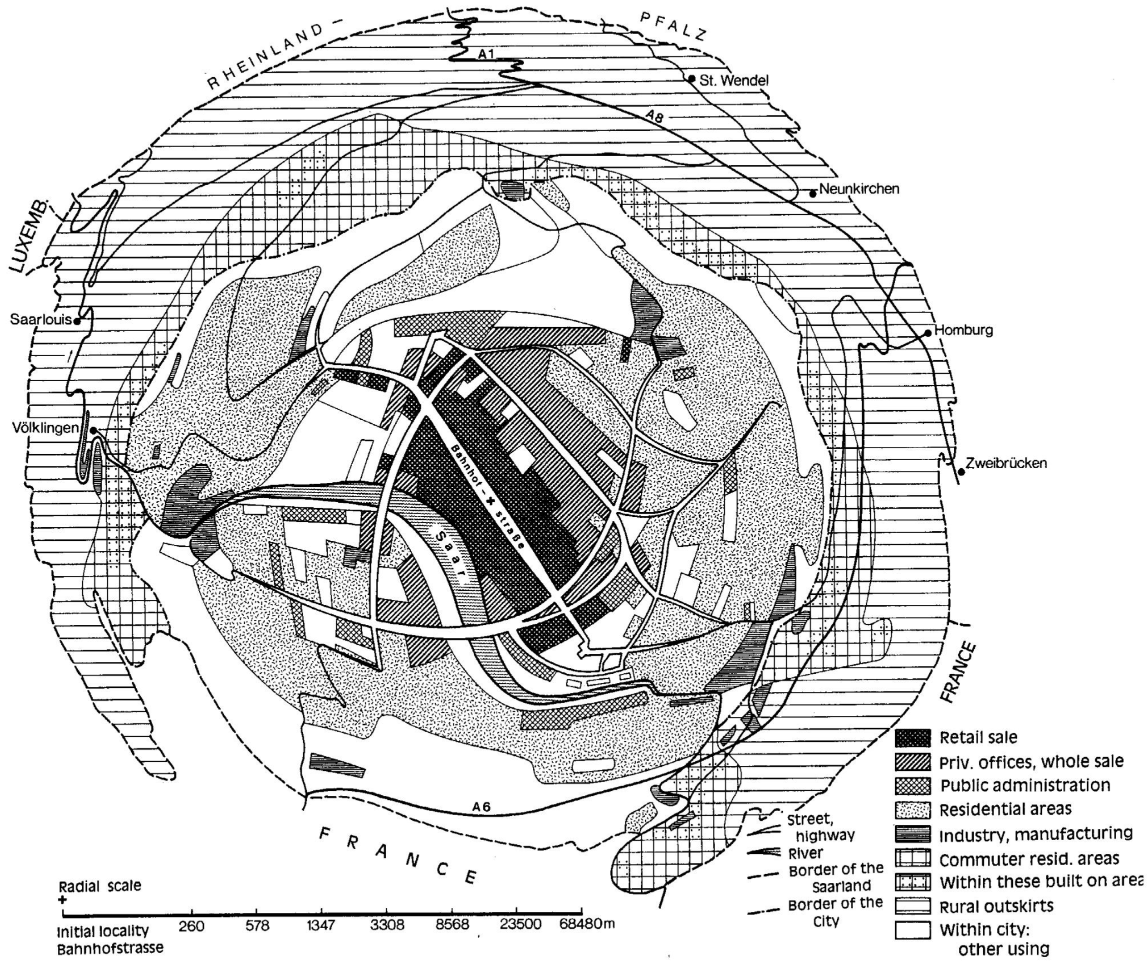
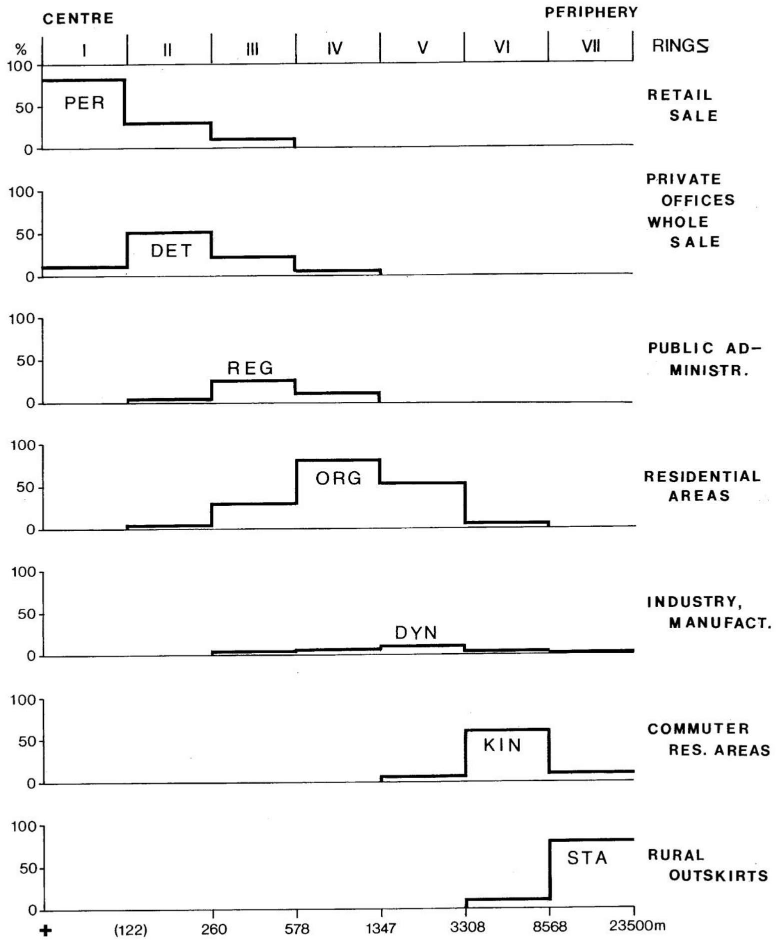


Fig. 24:
City-umland system Saarbrücken/Saarland (result of mapping in the 1970s):
Zoning of socio-economic activities.
The distance from the centre to the periphery was entered according to the potential scale.
b) Distribution of utilisation activities or tasks of the city-umland population of Saarbrücken on the zones in cross section. In the arrangement of the rings, the scale of tasks can be seen in accordance with the process sequence perception ... stabilisation.
(Source: see "Notes on the figures").

Fig. 24 b:



represents the same proportion of the final sales price as before. Thus, in certain sectors, the markets are dominated by extensive trans-regional and trans-national fields of influence. The cultural activities of the towns have also become less attractive. All this promotes change in the structure of production and population of the city-umland-populations. Nontheless, the central-peripheral organisation of the population itself, i.e. of the actual system, is clearly recognisable.

Technical systems:

In many technical systems too, energy and/or information is transformed. These systems are also non-equilibrium systems which carry out their work continuously. Technical non-equilibrium systems are tools in the hands of human beings. They function in accordance with the process sequence. The adoptive and reactive tasks are generally specified by man or are controlled or taken over by him. It is mainly the

productive stages, i.e. the actual transformation of energy (kinetisation) which is left to machines. One example of this is the steam engine.
- Perception: Stimulus from the superior environment (man) to set the machine in motion.
- Determination: The machine is ready for operation. It can be run as required by man if all the conditions are right.
- Regulation: Control of the machine is exercised by steam-pressure valves, speed controllers and other devices. Lubrication is also carried out to a certain extent automatically. However, the functioning of the machine as such must be supervised by man.
- Organisation: The parts of the machine have been arranged (by man) in such a way that the machine can run when water and coal are put into the system in sufficient quantities.
- Dynamisation: The machine is filled and stoked with water and coal (from the inferior environment, i.e. a water tank resp. a coal bunker).
- Kinetisation: Heat is developed, the steam from the boiler drives the mechanism (transformation of thermal to kinetic energy).
- Stabilisation: If filled with water and stoked constantly with coal, the machine will run according to man's requirements.

Thanks to the development of control technology, machines now exist which are able to carry out several tasks on their own. Also the computer is a man-made machine. Its designers created it to process information and to provide useful data (as products) which enable other machines to process material products in accordance with the given information.

But self-organising machines, i.e. machines which are able to adapt their form to constantly changing circumstances have not yet been developed. In our view this would require duplication of the entire process sequence at the 4 process levels.

2.4.4.2. Organic and inorganic non-equilibrium systems

The biotic non-equilibrium systems form the second large group in this type of system. It includes the cells and organs, but also the biotic populations such as the area systems, species and kingdoms. Living organisms play a particularly important part here. They transform energy, i.e. they produce. They are also programmed in such a way that they can organise themselves, i.e. that they can structure their elements and processes in such a way that they can fulfil this task while consuming as little energy as possible. Besides this, living organisms are also autopoietic systems, i.e. systems which organise themselves not only structurally like the non-equilibrium systems, but can also reproduce themselves materially and are therefore integrated in the general energy cycle through their own corporeality. They therefore also belong to the 6th stage of complexity (see section 2.6).

Systems in the micro and macrocosmos (e.g. atoms, molecules, star systems and galaxies) also occupy a double position. On the one hand, they constantly convert energy as non-equilibrium systems. On the other hand, they also create themselves materially.

In our order of magnitude, i.e. in the mesocosmos (see section 1) inorganic non-equilibrium systems as enduring self-maintaining structures characterised by division of labour and task processes do not seem to exist. However, many flexible constantly changing non-equilibrium systems in the large compartments of the earth's crust (litho-, hydro-, and atmosphere) such as tornados, tropical hurricanes or the depressions in the temperate zones must also be included. These non-equilibrium systems are on the move and exist only for a few hours or days before breaking up again.

2.5. Hierarchy processes and hierarchy systems

2.5.1. The textile factory

The factory was bound up in a web of economic and social relationships. It had to sell the fabrics (cloth and blankets) it produced, but on the other hand, it had to purchase the raw materials and a multitude of other goods, machines and services. It also required workers, which, as independent individuals, had to be able to lead their own lives culturally and economically in the society in which they lived.

The factory was situated in a small town and was therefore part of that community. It paid taxes and other duties to it, but also benefited from the services it provided. The community is traditionally responsible for the local infrastructure, i.e. for the way in which land is used, for the construction and maintenance of roads, bridges, schools, sports facilities, cultural institutions etc. On the other hand, the community must ensure the protection of the environment, conservation of the landscape, disposal of waste and sewage. It is the infrastructure which makes it possible for the organisates to function. Besides these, there are private central institutions (organisates) such as shops, cinemas, doctors' surgeries, chemists, banks etc. which are generally grouped around the centre of the community where they are easily accessible for the inhabitants. All the places of importance for day-to-day business can be reached in a relatively short space of time (in smaller communities in less than an hour) either on foot or by public transport. The community offers the organisates not only the environment they require, it is also the living space of its inhabitants. These inhabitants live with one another and develop their own forms of social communication. Common festivities, clubs and social institutions, assistance among neighbours bind the people together, are the expression of a strong social coherence which also includes social control.

The smaller communities are linked with the nearest large city by public-transport systems and private vehicles. It is the economic and cultural centre of the region, with a vast range of shopping facilities, banks, insurances, medical specialists, hospitals, theatres, institutions of advanced education and many other services. As a large industrial centre, it also offers employment to those who find no suitable work closer to their homes and have to commute daily. The country surrounding the city provides it with the greater part of its foodstuffs and provides recreation and living space to many of those who work in the city. Thus, besides the rural and small-town communities, a population has become established which is based on the city and its surrounding district: the city-umland population. Its function is to permit a balance between the industrial and the land-based agricultural activities in space (see section 2.4.4).

This population is in turn subject to the state which guarantees safety and the protection of the law. For this purpose too, taxes have to be paid. Certain restrictions on individual freedom have to be accepted, although every citizen requires a clearly established legal framework for self-fulfilment. The police are present in the community, but it is principally the legislative and executive functions exercised by the state which make it possible for the organisates to develop economically and benefit from the markets and finance industries. Some of these state functions are fulfilled by local government institutions.

The inhabitants of the communities, city-umland populations and states are generally also members of a religious community. The church as an institution conveys religious and philosophical, i.e. "eternal" values, and sets ethical standards. They are a constituent part of the culture, whose carriers are the entire cultural population, e.g. of Europe, the Orient, Eastern Asia.

Thus, society appears to be a hierarchically structured formation composed of populations. As an organisate, the textile mill occupied a certain position - as a socio-economic population in which individuals worked and produced. The organisate provided the economic basis for the individuals working in it and enabled them to resolve their personal cultural, physical and biotic problems (as expressed in nourishment, reproduction, rearing of children, provision for old age etc.).

2.5.2. General considerations

Every working person is on the one hand part of the socio-economic hierarchical system which we will term "mankind as society" and, on the other, as a living creature, part of the biotic hierarchical system which we will term "mankind as species" (see section 2.5.4).

Here, we are primarily concerned with membership of mankind as society. In order to cope with their working lives, individuals have a multiplicity of different problems to solve. This is only possible because they are embedded in this hierarchy which relieves them from certain specific tasks which they are unable to fulfil themselves. Each individual belongs to a population in the hierarchy and entrusts it with certain tasks:

- Thus, the individual appears both as worker and consumer.
- The organisate organises the work of the individual.
- The community is responsible for creating and maintaining the infrastructure necessary for the work of the individuals and organisates.
- The city-umland population joins the individuals, the organisate and the community through intercourse with other individuals, organisates and communities in space, thereby ensuring that the raw materials, goods and services are distributed and that the people can travel beyond the boundaries of the community.
- Through its constitution, laws and their enforcement, the state assures order and supervises the rules by which the citizens can pursue their activities undisturbed.
- Both directly and through the organisation as state, the cultural population conveys to its members the code of values which serves as a basis for its activities and processes.

From this synopsis, the following facts emerge:
1. The population types have certain tasks for society. These tasks are given thematic form within the framework provided by the institutions of work, consumption, traffic etc. On the one hand, the institutions reflected in these responsibilities and activities serve to divide the individual hierarchical population levels from one another vertically, and on the other to link them together horizontally.
2. At the hierarchical levels, the populations fulfil their tasks through processes (see section 2.4). These too are in a hierarchical relationship to one another. The populations provide work for the hierarchically superior populations. This should be reflected in the duration of the processes. On the other hand, the populations are independent structures which are concerned with maintaining their existence, as are all non-equilibrium systems. This means that besides the task for the hierarchical system of mankind, the populations also have tasks to fulfil which concern only themselves.
3. The individuals not only have advantages from belonging to the population hierarchy. They must also submit themselves to it. This results in a relationship based on order and obedience in the hierarchical system of mankind as a society. The hierarchy consists of levels which represent institutions thematically (see above) and flow-equilibrium systems (see section 2.3) i.e. compartments structurally (as sub-systems). These flow-equilibrium systems are composed of the self-organising populations of the same type. The individuals in their roles are the elements both of the hierarchical system and of the populations whose members they are. The populations compete with one another, thereby producing selection. Through

the hierarchy and selection, self-control and structural self-creation of the society as a whole becomes possible.
4. The hierarchy also takes effect in the spatial arrangement of populations since the superior populations encompass the inferior populations spatially. Thus, not only comprehensive control is possible, but the variety of natural resources in the ecumene (as the inferior environment of mankind) can be used more effectively for man's purposes.

The hierarchical system and the hierarchical processes constitute the 5th level of complexity.

2.5.3. The model

Until now, the theoretical significance of hierarchical processes and systems has not received sufficient attention from the social-scientific community. We are also unable to present a mathematical description based on the process theory. We will therefore use examples to illustrate this topic. In doing so, we will return to the points discussed in the preceding section (2.5.2) while devoting our main attention to the following four subjects:
1. the catalogue of tasks and institutions of the compartments bearing the hierarchical levels,
2. the hierarchy of the processes,
3. the hierarchy of the populations and
4. the hierarchy of spaces.

2.5.3.1. The catalogue of tasks and institutions

Originally, mankind was a species like many others, i.e. a population, a non-equilibrium system, which fulfilled all the tasks fulfilled by any population intent on survival (see section 2.4). In the course of mankind's history, individuals have delegated more and more of the tasks necessary (or useful) for life, by coming together to form superior entities, i.e. new populations, and dividing up their activities or work. There are no completely self-sufficient individuals who can carry out all the tasks necessary for living themselves. Becoming human is causally bound up with the process of specialisation. This process of division and subdivision into specific tasks is part of cultural evolution and experienced a dramatic acceleration around 20.000 years ago with the result that mankind is now a highly complex structure.

In the last resort, it was most probably economic reasons (effectiveness) which were decisive for specialisation. The biotic necessities (health, recuperation, nourishment, reproduction etc.) have remained, whereas economy, technology, transportation etc. continued to sub-divide rapidly. Thus, mankind divided (as already mentioned above) structurally into two parts, which developed differently:

Mankind as species, within which individuals satisfy their biotic requirements, and mankind as society, responsible for the optimum utilisation of environmental resources, for energetic supply and for comfortable conditions of living (see also section 2.5.4). Each individual belongs to both types of mankind. In order to understand and categorise the multitude of tasks and activities of humans from their structural side, we must proceed step by step.

We can approach such a categorisation in four steps, starting from the acting individuals:
1. As we said, each individual has two sides to his existence, the biotic and the social, which correspond to his membership of mankind as species and as society. Thus, his actions serve to satisfy his biotic requirements on the one hand and his social and economic requirements on the other. The processes and populations are divided in the same way. For reasons of space, we will deal only with mankind as society.
2. Furthermore, as stated above in section 2.4, the actions and processes are either market-oriented, i.e. they are imposed from outside and are carried out in accordance with the (biotic or) social necessities expressed therein ("induction"), or they serve the purpose of regeneration, in order to be fit for the next action or process ("reaction"). Here again, it is possible to subdivide into information processing ("adoption", "reception") or energy (material) processing actions and processes ("production", "reproduction").
3. Depending on their position within the scale of "tasks", the actions and processes have constantly recurring thematic fields. We can distinguish a catalogue of 7 tasks both in the induction and in the reaction process. The tasks of perception, determination, regulation and organisation (inasmuch that it is part of adoption) are devoted to processing information, while organisation (as part of production), dynamisation, kinetisation and stabilisation are devoted to energy processing.
4. The single actions resp. processes are concretised, i.e. thematically institutionalised. This includes a division of human activities according to the tasks, i.e. the thematic or qualitative aspects. In institutions, this thematic division through different norms and organisational forms (as well as through feedback, see section 2.3.2) is given permanent form with the result that they represent components of order which are generally accepted by society.

In some comprehensive institutions, the basic socio-economic activities and processes are easily recognisable. Mankind as society must fulfil the tasks listed above (perception ... stabilisation) in order to exist.

One might now enquire which of the institutions may be assigned to a specific task. These institutions which are, so to speak, of the highest rank are described as "basic institutions" (1981, pp. 82 f.).

- In order to have a foundation for vital decisions, it is first necessary to obtain information. "Perception" appears as a task. It is the essential pre-condition for all (non-spontaneous) action. "Knowledge" and "science" as well as "art" are the basic institutions. They are founded on perception, and this is, in a general sense, essential for allowing mankind to cope with its environment and adapt its behaviour to it.
- How humans act depends (in the last resort) on their basic attitude to life and their environment. It is a decision. In the catalogue of tasks, "determination" now appears. "Religion" (as a basic institution) as well as the conveying of values in general, give mankind its fundamental orientation, its sense. They establish the desired, if not always achievable, ethical ideal. They affect the manner in which they live, their "culture".
- "Authority", "power" and "rule" form the basic institutions connected with the task of "regulation". They form the framework within which the process steps can be co-ordinated, in which the passage of information can be controlled. Without control, no co-ordination is possible, and work is dissipated without effect.
- "Transportation" (as a basic institution) permits spatial "organisation". The resources of the inferior environment can only be utilised to the best effect by linking the differing advantages of the various localities with one another.
- The utilisation of the energy resources of the inferior environment, i.e. the task of "dynamisation" is made possible by the creation of the "infrastructure" (as a basic institution), among other things of the earthbound artefacts (see section 2.1.2).
- The "processing" of the products themselves (as a basic institution) is defined by the task of "kinetisation". It is linked with the division and organisation of work. This may involve completely different things and the product may be of material or immaterial type.
- Planned physical and intellectual activity may be defined as work. The remuneration for work allows man to satisfy his requirements. "Work" and "consumption" are the basic institutions located at the end of the scale, thereby fulfilling the task of "stabilisation".

In Tab. 1, the results of this section are summarised.

Seen from a general point of view, a qualitative or thematical hierarchy appears, a scale which demonstrates the degree of dependency. Knowledge is essential for living, for dealing

Tab. 1: The basic institutions and the basic tasks of mankind as society:

Basic institutions	Basic tasks
Science, art	Perception
Religion	Determination
Rule, power	Regulation
Transportation	Organisation
Infrastructure	Dynamisation
Processing	Kinetisation
Work and consumption	Stabilisation

with the environment. The form of living (culture) must adapt itself to this. Power on the other hand is only conceivable within a cultural framework. And the control which it creates is essential for functioning transportation. Without transportation, no framework (infrastructure) for economic activities (production) can be created, no systematic work carried out and no consumption enjoyed.

The assignment of the tasks and institutions to the population types will be dealt with later (see section 2.5.3.3).

2.5.3.2. The hierarchy of processes

All these institutionalised tasks are constituent parts of human existence. They must be realised in temporal succession, i.e. in processes. We must take this into account in two respects:

1. Mankind as a society is in general undergoing change. A constant change can be detected, renewal against the background of social change. The renewal does not take place continuously, but in the shape of innovations (about the diffusion of innovations see section 2.3.2 and 2.3.4.2). In reality, the above-mentioned list of tasks is worked through step by step in the form of a process sequence, it begins with perception, determination then follows, then regulation etc.
2. At the various hierarchical levels, the processes in the populations take place at different speeds. The validity of established views, technical standards, fashions etc. lasts for different lengths of time. There are "eternal values", i.e. those which are unshakeable, in particular the accumulated knowledge of the world and the basic ethical standards. Besides, the term "longue durée" (BRAUDEL 1958/92) can be applied to state policies, large-scale technical

installations (e.g. the railways), artistic periods which may involve many decades or even centuries. The local infrastructure of economic activity has to be changed more frequently, every few years. Finally, the yearly, monthly, weekly and daily periods should be mentioned, which strongly influence the conditions of life and work in their details.

If one establishes that the inferior processes provide work for the superior processes, one can come to the conclusion that the processes differ by the factor 7, because each process sequence (induction process) comprises 7 stages (perception ... stabilisation). Actually, - and this is suggested by the inductive results of earlier studies (1981) - the average number is 10. Why this should be so is not well understood. In particular, this factor 10 becomes apparent in the processes higher up the hierarchy. With the shorter processes, there are variations primarily because nature imposes a different rhythm (yearly rhythm, daily rhythm).

The cyclic structure of processes observable in the "rhythms" is due to the feedback at the end of each induction and reaction process (oscillations; see section 2.3.2, 2.3.4.2, and 2.4.3.2). If we carry out a classification (see table 2), we define the duration on the basis of the individual process stages (perception, determination etc.) and not on that of the overall process sequence of the induction process.

Specifically, the result is as follows (for sources, see 1981 etc.):

The principal process is that of "cultural evolution". In the earlier palaeolithic era, humans were hunters and gatherers. They spread over the earth little by little and so created their living space, the ecumene. In the later palaeolithic era, a new chapter in the history of mankind began. The rapid growth of humanity was accompanied by the invention and spread of innovations, in particular of technical equipment for economic purposes, which indicates increasing knowledge of the (energetic) environment and the possibility of its utilisation. The hunters and gatherers became more differentiated. The tasks of society incorporated in the basic institutions gradually became more specific and a hierarchy came into being. In this way, mankind took the form of a hierarchical system, mankind as society. Mankind perceives the possibilities in its environment, accumulates knowledge and with this knowledge, creates the basis for its own existence. In the hierarchy of processes, this corresponds to the basic task of "perception" (see section 2.5.3.1). The state of knowledge is reflected in the processes. Different stages become apparent, which are initiated by "revolutions" (see in particular CHILDE 1936/51). They show (provided we are correct) that mankind as society develops in a process, each

of whose stages take several thousand years, i.e. in "millennium rhythm". The following is a brief summary of this process:
- "Late palaeolithic revolution" (approx. 25.000/15.000 B.C.): fine arts (basic institution of perception) experienced their first heyday, especially in the franco-cantabrian region.
- "Mesolithic era" (beginning around 12.000 B.C.): No precise knowledge available. Apparently, the first solid houses began to be built in the southern Anatolian and neighbouring regions, even though the economy was still based on hunting and gathering.
- "Neolithic revolution" (approx. 9000/7000 B.C.): Introduction of cultivation in the "fertile semicircle" (i.e. in the wide strip of territory to the west, north and north-east of the Syrian and Mesopotamian desert), accompanied by a sedentary mode of life. Structures of domination or rule may also have come into being (basic institution of regulation ?);
- "Urban revolution" (approx. 3000 B.C.): urban cultures appear for the first time in Mesopotamia, accompanied by a re-orientation in transportation (basic institution of organisation);
- "Industrial revolution" (approx. 1800 A.D.): The period of colonisation begun by Portugal and Spain at the end of the 15th century opened up new sources of raw material. The actual industrialisation began in England. It made possible the utilisation of energy of non-human and non-animal origin to an extent previously unimagined (basic institution of dynamisation).

Hierarchically, the next lower level is formed by processes whose stages cover several hundred years ("centennial rhythm"; see fig. 25). At this second level, religion is created, the

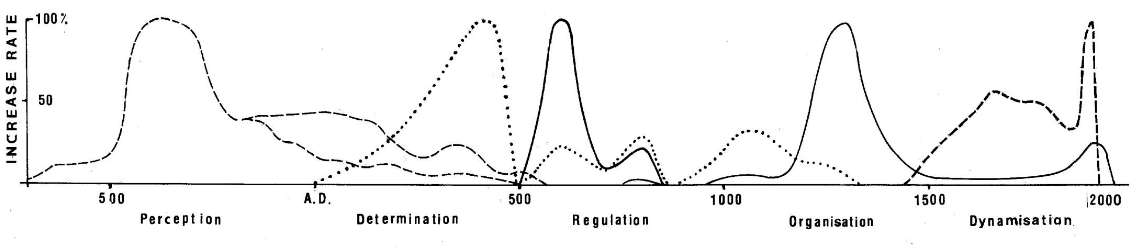


Fig. 25:
Process in centennial rhythm:
The development of Europe as a cultural population began in classical antiquity and continued in the early, high and late middle ages into early modern times. The five stages are assigned to task stages (see text). (Source: see "Notes on the figures").

fundamental decision in the shaping of one's own culture. This is the basic task of "determination" in the hierarchy of

processes. As an example we try to interprete the creation of European culture (on the basis of the known historical periods; 1997, pp. 106):
- Classical antiquity (approx. 500 B.C. up to approx. the birth of Christ): formation of art, philosophy, science in Greece and the Roman Empire (perception);
- Late antiquity (birth of Christ up to approx. 500 A.D.): spread of Christianity in the Roman Empire (determination);
- Early middle ages (approx. 500 up to approx. 900 A.D.): creation of state systems and administration, especially within the Frankish Empire (regulation);
- High and late middle ages (approx. 900 until approx. 1500 A.D.): formation of municipalities and improved transportation (organisation);
- Modern period (approx. 1500 up to approx. 1900 A.D.): acquisition of colonies, exploitation of raw material and energy resources of the earth from Europe (dynamisation);
- Present (since approx. 1800): industrialisation, multiplication of productivity (kinetisation?).

The "decennial rhythm" covers several decades with an average of 50 years. It is apparent in a large number of ways e.g. in the so-called Kondratiev Cycle (SCHUMPETER 1939/61), in historical periods (e.g. Renaissance, Reformation, Absolutism, railway age, various industrial periods etc.). A more exact study of the stages and their assignment to process sequences has yet to be made, although good material is relatively easily accessible (e.g. 1981, pp. 88, 116, 142 etc.).

As examples, we may take the early industrial development in Germany (see fig. 26) and the overseas colonisation by European powers (see fig. 27).

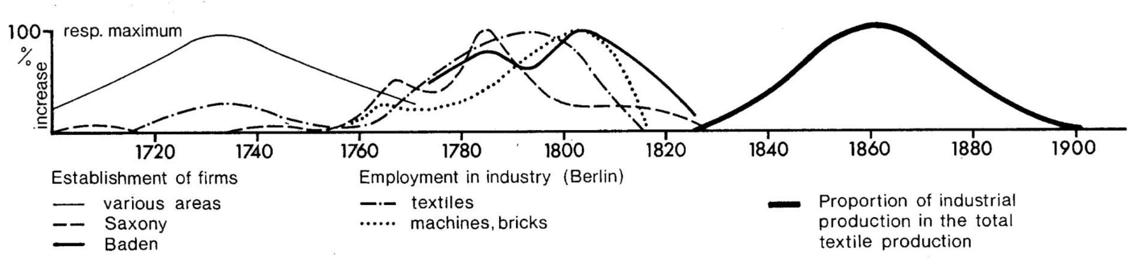


Fig. 26:
Processes in decennial rhythm:
Early industrialisation (1700 - 1900) in Germany, shown according to various criteria (manufacturing industry in several areas of Germany, beginning of the textiles industry).
(Source: see "Notes on the figures").

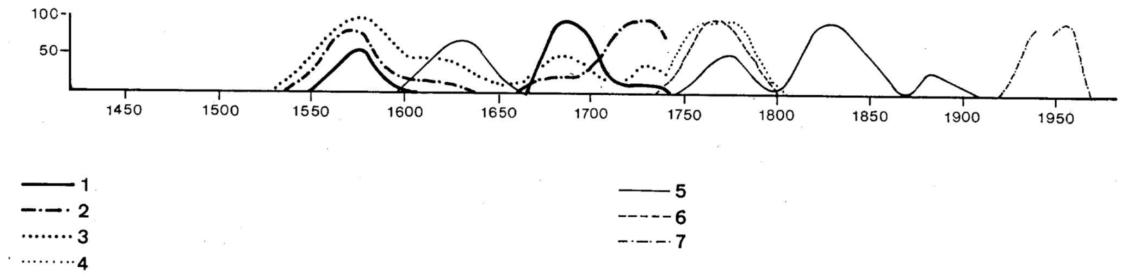


Fig. 27:
Prozesses in the decennial rhythm in Central Europe:
1. Colonisation of the Huguenots, Waldenser etc. in Hesse,
2. Colonisation in Brandenburg (before 1740),
3. Colonisation in den Eastern Sudetenland (before 1740),
4. Colonisation in Prussia (after 1740),
5. Veen colonisation in the Netherlands und Eastern Frisia,
6. Bog colonisation in the kingdom of Hannover,
7. Colonisation in the Emsland.
Highest rate of growth in each case = 100.
(Source: see "Notes on the figures").

Even the "several-year rhythm" whose stages last for an average of 5 years has not yet been sufficiently studied. At this level, society is ordered spatially (in the hierarchy of processes, the basic task of "organisation"). This is seen in the migratory movements, e.g. to and from a particular city, between different states (see fig. 28), and probably in the expansion of the functional areas of the city (central business district, residential, industrial areas etc.; see section 2.4.4.1). This rhythm is also apparent for example in the shorter economic cycles, growth rates and trend figures.

The "yearly rhythm" can be observed particularly easily in infrastructural measures, e.g. in settlement activity (in the hierarchy of processes, the basic task of "dynamisation"). A good example of this is the foundation of the settlement of Wörpedorf during the Hanovarian colonisation of moorland near Bremen in the 18th century (LILIENTHAL 1931; FLIEDNER 1999, S. 131):

- Before 1747: general deliberations on the possibility of taking the moor into cultivation, preliminary surveys (perception);
- August 1747: decision to survey the moorland (determination);
- 1749/50: process of colonisation established, quarrels with neighbouring communities settled (regulation);
- July 1751: instructions to colonise the moorland, thorough

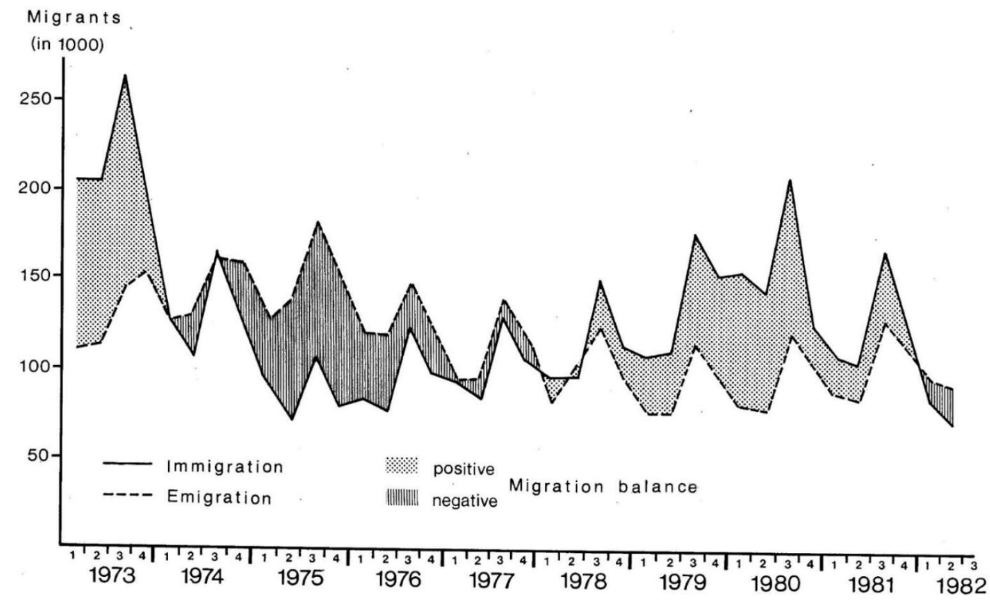


Fig. 28:
Processes in several-year rhythm:
Migration of foreigners in the Federal Republic of Germany (1973 to 1982). The annual rhythm is expressed in the absolute immigration and emigration figures, the several-year rhythm in the balances.
(Source: FRIEDRICH and BRAUER 1985. See "Notes on the figures").

planning of land allocation (organisation);
- July/August 1751: recruitment of peasants for cultivation work (dynamisation);
- Autumn 1751 - 1753: execution of work (purchase of building material, erection of huts, excavation of ditches, channels, locks, planting of trees etc.) (kinetisation);
- October 1753 - 1755: inspection by government commission, all posts are occupied, officials of self-government are nominated (stabilisation).

The yearly rhythms are also reflected for example in the activities resp. unemployment (see fig. 29). The fact that the individual stages are so easily apparent, depends on the weather conditions in the different seasons.

The execution of the processes in detail (in the hierarchy of processes, the basic task of "kinetisation") is carried out in the "monthly" or "weekly" rhythm, with the result that the work is completed within one year. On a farm or in an industrial company (see section 2.4.2):
- the requirement for goods is determined on the market (perception);
- decision what is to be produced (determination);
- planning of the work (regulation);
- contacting the inferior environment to obtain energy and raw materials (organisation);

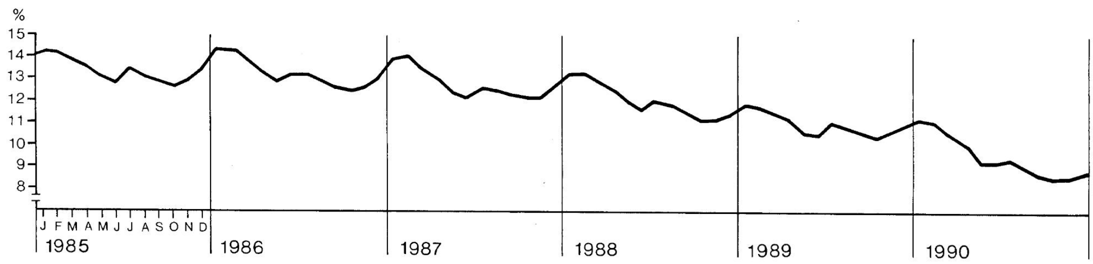


Fig. 29:
Prozess in yearly rhythm:
Unemployment (percentage) in the Saarland 1985 to 1990.
(Source: see "Notes on the figures").

- raw materials and semi-finished goods are brought to the places of work (dynamisation);
- actual production (kinetisation)
- sale of the products on the market (stabilisation).

Finally, individuals plan, work, eat and recuperate on a "daily rhythm" (in the hierarchy of processes, the basic task of "stabilisation") according to the possibilities at their disposal and the constraints to which they are subjected. Here, there is little or no process sequence involved.

Table 2: The basic tasks of mankind as society and the duration of the processes:

Basic tasks	Duration of processes (stages)
Perception	millennial rhythm (approx. 5000 years)
Determination	centennial rhythm (approx.500 years)
Regulation	decennial rhythm (approx. 50 years)
Organisation	several-years rhythm (approx. 5 years)
Dynamisation	yearly rhythm
Kinetisation	monthly - weekly rhythm
Stabilisation	daily rhythm

Through the established process sequence, i.e. its fixed program (teleonomic processes; see section 1), the overall process of cultural evolution appears as an oriented process which continuously shapes human society with many variants, at every level and in every stage, thereby leading to ever-increasing complexity. The course of the process is determined by legitimacy and individuality, necessity and chance.

It is within this framework that the reaction processes take place, i.e. in the populations of the various hierarchical levels. This either preserves or changes the structure of the entire hierarchical system.

Table 2 summarises the results of this section.

2.5.3.3. The hierarchy of populations

As shown above, 7 levels can be identified in the hierarchy of mankind as a society. These differ from one another in their tasks and institutions as well as in the duration of their processes. The processes in these various hierarchical levels are carried out by populations. These are the carriers of these processes. The question now arises as to how the populations co-operate with one another from one level to another.

The populations are integrated in the hierarchy in a double sense, i.e. through the flow of energy and through control i.e. through the order-obedience relationship (see fig. 30).

Flow of energy in the hierarchy of populations

Let us first of all consider the flow of energy by returning to the treatment of tasks and institutions (see section 2.5.3.1). The hierarchical system must be understood in terms of the vertical flow of information (demand) and energy (supply), i.e. in the same way as the flow-equilibrium or non-equilibrium system. If we assume that mankind as a society developed from mankind as a species primarily as a result of economic requirements (see sections 2.5.3.1, 2.5.3.2, 2.5.4), mankind as a species can be regarded as the energetically superior environment of mankind as society. The energetically inferior environment is the ecumene, the living space of mankind on the earth with its resources. From an energetic point of view, the hierarchical levels take the form of bonding levels, which, as with a flow-equilibrium and non-equilibrium system (see sections 2.3.2 and 2.4.3.2) are passed through gradually.

- At the first level mankind as a population (it is the largest population of mankind as a society with a certain task) has contact with the hierarchically superior environment, i.e. mankind as a species. By nature, humans possess an organism which is identically equipped with senses which permits them to perceive the advantages and disadvantages of nature as a vital resource. The acquisition of such knowledge (task "perception", basic institutions science and art), should be regarded as the task assigned to mankind (as mentioned above).

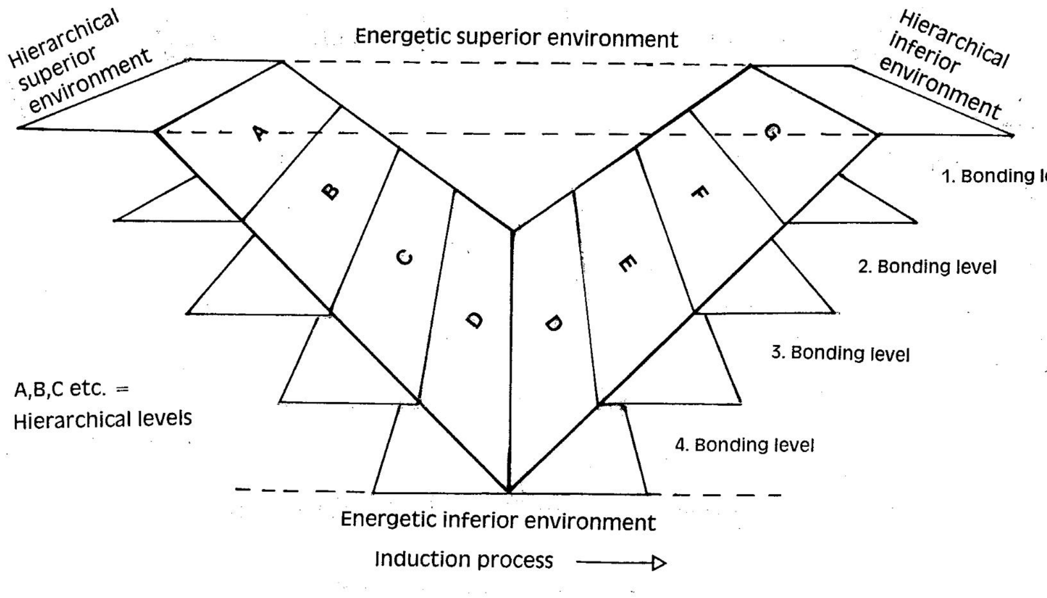


Fig. 30:
The hierarchical process (induction process) and its environments.
The hierarchic should be distinguished from the energetic environments. The four bonding levels which take the flow of information from the energetically superior environment from A (perception) to D (organisation) to the energetically inferior environment ("adoption"), as well as the flow of energy from D (organisation) to G (stabilisation) to the energetically superior environment ("production") can be seen (see also fig. 15). In this process sequence, the hierarchical levels from the hierarchically superior environment via mankind as a population (A) and the city-umland population (D) to the individuals (G) and the hierarchically inferior environment are also passed through.
(Source: see "Notes on the figures").

- At the second level, religion represents the most important basic institution (task "determination"), whose carriers are the "cultural populations". These are the units which appeal to certain agents of religion or a certain code of values (culture), which are distinguished by a certain view of life, a definable position in the cultural evolution, i.e. by the degree of division of work.
- The framework conditions for the basic institutions of authority, power and rule, i.e. for the task of "regulation", are guaranteed by the "state", the population of the state. It ensures that the actions and processes are carried out in accordance with law and order.
- The "city-umland-population" (see section 2.4.4.1) is the population type in which the basic institution of transportation is optimised, i.e. in which the task of "organisation" is implemented. Ideally it links the services and the trades at the centre with the agriculture and the recreational facilities in the surrounding country.

The city-umland population serves to transport information, but also to transport energy in the form of raw material and goods. Here, the population types in the hierarchy are divided between those which serve the processing of information and those which serve the processing of energy. Whereas the populations situated higher up the hierarchy process more abstract information (science and art, fundamental outlook and control), those lower down the hierarchy are concerned with the activities devoted directly to the processing and distribution of energy.

- The control of the utilisation activities is the responsibility of the "community". It permits orderly contacts with the inferior environment by creating a suitable infrastructure (as basic institution) i.e. it fulfils the task of "dynamisation".
- The "organisate" (e.g. farm, small business holder, practice, administration office, enterprise, plant) is the population in which the actual processing (as basic institution) has its place, i.e. the task of "kinetisation". Within the organisate, the work is shared and the transformation of energy into products optimised.
- "Individuals" are right at the bottom of the hierarchy (task

Table 3:
Population types in mankind as society corresponding with the basic tasks and basic institutions (see table 1):

Basic tasks	Population types	Basic institutions
Perception	mankind as population	Science, art
Determination	culture population	Religion
Regulation	state	Rule, power
Organisation	city-umland-population	Transportation
Dynamisation	community	Infrastructure
Kinetisation	organisate	Processing
Stabilisation	individual	Work and consumption

"stabilisation"). They combine the basic institutions of work and consumption. The individuals (in their roles) are the elements in the hierarchical system which is formed by the populations of mankind. They receive their income from the services they provide, and must also provide services for the superior populations.

Table 3 provides a summary.

The control of the hierarchy of populations

The most important aspects can be shown in a model (see fig. 31). The circular process patterns (see section 2.4) at the various hierarchical levels of mankind as society are depicted in the foreground. The various population types with their obligatory tasks follow from top to bottom. In the inferior populations, the processes take only one tenth of the time of the superior ones (in the logarithmic representation in the figure). The flow of information is from top to bottom, i.e. the orders come from above and are passed on downwards. Compliance with the orders is from the bottom upwards. The processes take place from left to right, the feedback from right to left.

This model (which is of course capable of further extension) is probably as complete as is necessary for the purpose of simulation.

But the hierarchy is held together by the context of order and obedience (control hierarchy), where the demand for the performance of work passes vertically downwards to the individual via the control hierarchy, and the provision of the work vertically upwards (see fig. 30). Mankind as a species as a whole appears as a hierarchically superior environment and is therefore identical with the energetically superior environment. On the other hand, the inferior control environment must be kept distinct from the energetic. The inferior control environment is the the physis of mankind, the labour, it is located "beneath" the individuals (in their capacity as elements of mankind as a society) and regarded from a systematic point of view also belongs to mankind as a species. The order(s) descend(s) from the top level, from mankind as a population downwards step by step to the individual, and obedience proceeds from the bottom upwards (see fig. 32).

All the hierarchical levels of mankind as society are involved. The populations are required to fulfil their task and they do this by working through the process sequence in their own rhythm. The non-equilibrium systems obey the orders, because their existence depends on their integration in the flow of information and energy. So the information and energy can be transmitted between the demanding consumers and the supplying producers in exactly the form required.

The different population levels are coupled to one another in such a way that the inferior populations supply the superior systems with work. We can thus distinguish between the hierarchically superior and the hierarchically inferior

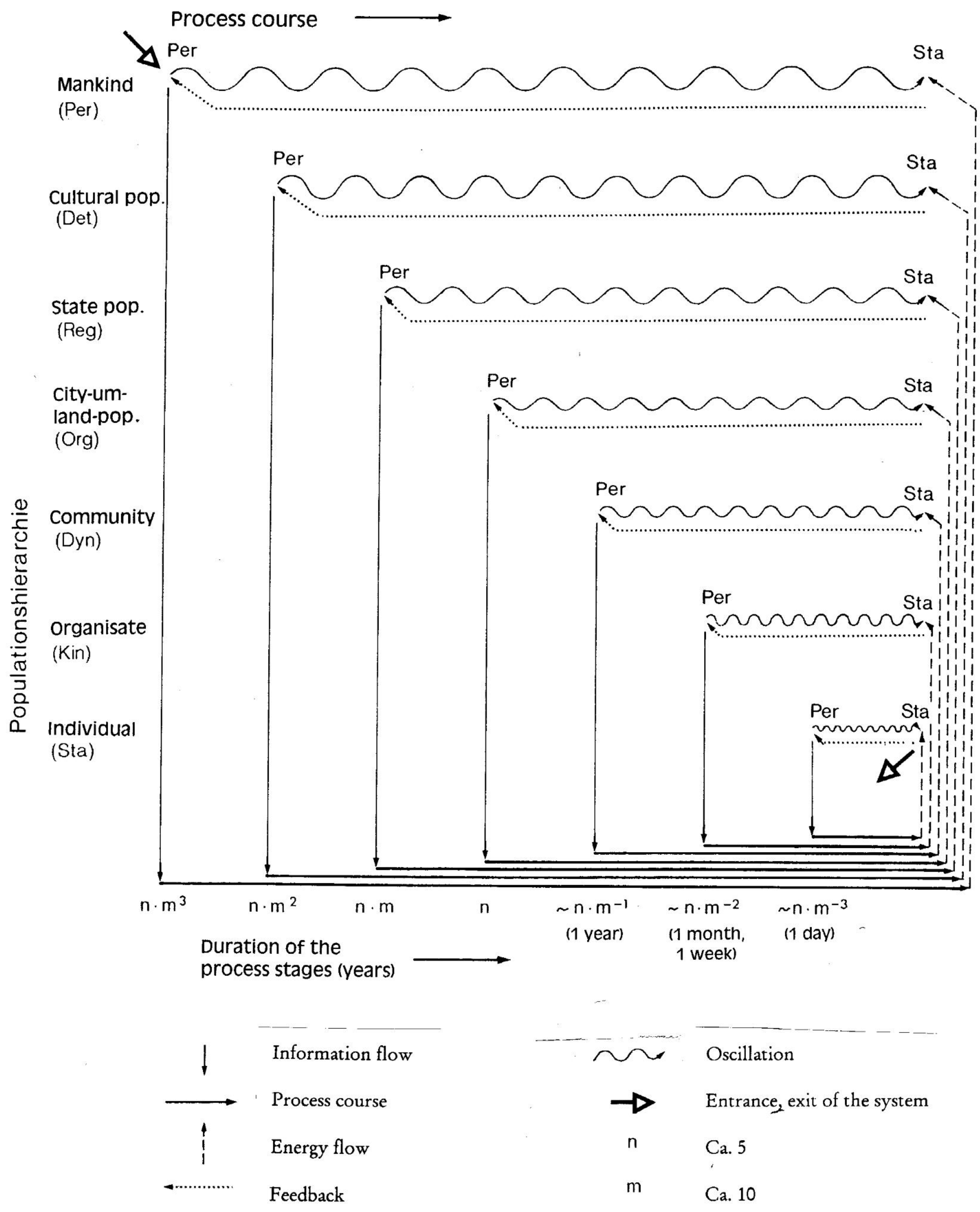


Fig. 31:
Structural model of mankind as a society.
It clearly shows the hierarchy of the populations and the circular course of the processes (see also fig. 16). In each case, the flow of information is from top to bottom, the flow of energy from bottom to top, while the course of the processes is shown horizontally from left to right and the feedback from right to left. The process duration is shown downwards from population type to population type to the individual on a logarithmic scale.
(Source: see "Notes on the figures").

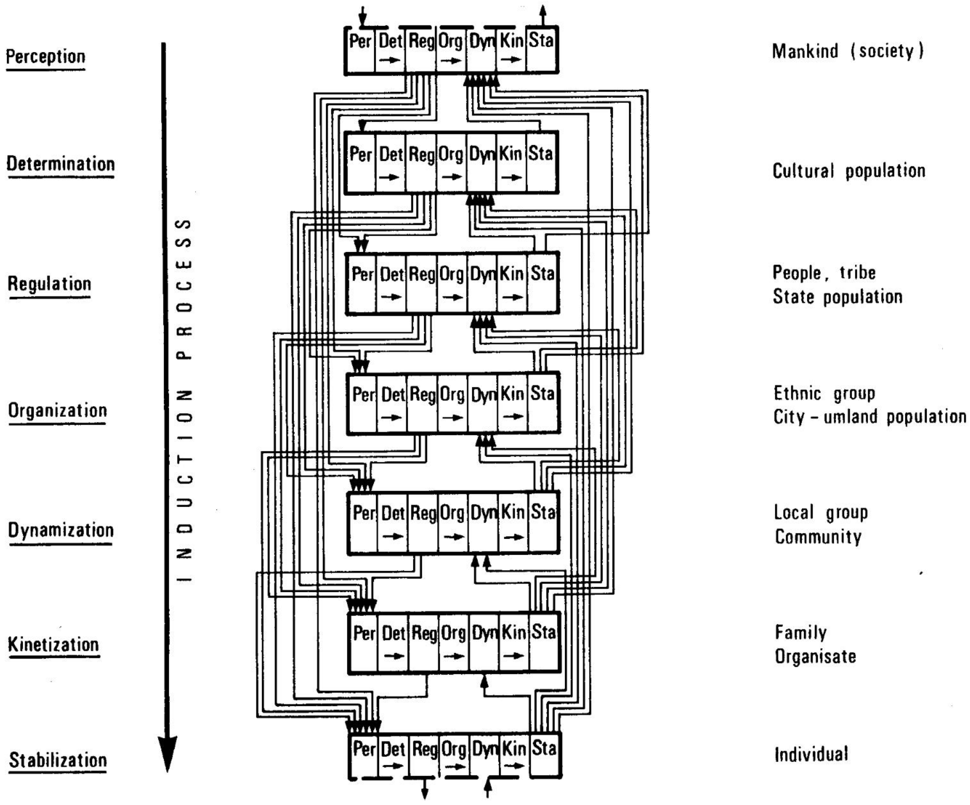


Fig. 32:
Hierarchical system of mankind as a society.
Linking of processes of the various hierarchical levels. Control of the population of mankind as a society is only possible when the populations assigned to one another hierarchically communicate correctly, i.e. in process rhythm. The "order" is input into the inferior populations as demand from the top downwards and these pass it on to the populations inferior to them in the regulation stage. Conversely, during the stabilisation stage the signs of "obedience" are passed upwards to the superior populations, which are located in the dynamisation stage (see fig. 21).
Only one population is represented symbolically at each hierarchical level. (Source: see "Notes on the figures").

environment. The number of inferior populations of the next lowest level belonging to a particular population type, form the elements of flow-equilibrium systems. In this way, the stimulus (order flowing from above) and the obedience (supply of work flowing from below) can change levels.

In contrast to the strict control in the vertical direction (i.e. between the hierarchical levels) the processes in the horizontal direction (i.e. at the hierarchical level) regulate themselves.

Selection and evolution become possible, because each non-equilibrium system is adjacent to other non-equilibrium systems of the same kind which are in the same (i.e.

competing) situation. Such non-equilibrium systems which cannot compete successfully do not survive while other new ones are formed.

In this way, the entire hierarchical system is created structurally (not materially; see section 2.6).

2.5.3.4. The hierarchy of spaces

The hierarchy of the basic institutions, processes and populations corresponds to the hierarchy of anthropogenic spaces. The spaces occupied by the populations are filled by the inferior populations.

Thus, the space occupied by the population of a state generally contains several spaces which are occupied by city-umland populations (see section 2.4.4.1; about central places see also section 2.2.4.2), and these in turn contain several which are occupied by communities. Thus, at each hierarchical stage, a mosaic of spaces of the same population type forms.

The spaces shaped by the hierarchical system are derived from those of the non-equilibrium systems. We must distinguish between the spaces which are shaped by the populations themselves, i.e. non-equilibrium systems, and the spaces which characterise the spheres of influence of the populations.

Spaces occupied by the populations themselves:

The spaces which are occupied by the populations themselves are also controlled by these. The individual populations exercise their internal control in various forms depending on their tasks. Thus, the spaces are shaped differently.

Populations which are located beneath the city-umland populations, are generally compact in shape and serve directly to process energy. With organisates, this is easily seen. As already established using the example of the organisate weaving mill (see section 2.4.1), the individual stages of the induction process are implemented in subsystems (departments), which give spatial organisation in a specific arrangement of population. This should be as favourable as possible for the production of the populations, i.e. when the circumstances permit, the elements are brought together in such a way that internal contact between the various work groups is facilitated.

In rural communities and small towns, assorting takes place between the central institutions at the centre, the residential area and out in the country areas. As already outlined (see section 2.4.4.1), this type of assorting can be seen in the city-umland populations in an extreme form. The city-umland population is made up of a compact core, the city, and a more thinly populated surrounding area, the "umland". Thus, the city-umland population occupies the position of intermediary. The populations at the hierarchical level above the city-umland populations are loosely structured. They are concerned principally with disseminating information, as is shown in our discussion of institutions and tasks (see section 2.5.3.3).

With larger populations, the intensity of the contacts declines from the centre towards the exterior and in many cases forms a bell-shaped space whose (intensity) surface rises steeply on the inside and drops gently towards the outside (perhaps conforming to the multi-nomial distribution; see section 2.4.3.2, no. 24).

Shaping of the fields of influence:

As already shown, the populations of the various types ideally adjoin one another in the ecumene without gaps or intervals, i.e. community adjoining community (apart from unsettled land and land now belonging of any owner), state adjoining state etc. Thus, they form continuously the hierarchical levels of mankind as society. Structurally, these hierarchical levels are flow-equilibrium systems, in which the populations (i.e. non-equilibrium systems) compete.

On the outside, the populations are surrounded by areas of influence which affect the levels formed structurally by populations of the same type. Examples of these are areas of supply and delivery and those providing the workforce for the organisates, and the areas influenced by overseas trade and foreign policy of the states. Here, the populations try to maintain and extend their influence, because their own existence depends on this.

These spheres of influence decline gradually in their intensity from the centre outwards, initially very quickly and then less and less, as mentioned already (similar to Newton's Law of Gravity; see sections 2.2.3, 2.4.3.1 und 2.4.3.2). The areas of influence are thematically specific, with the result that the same population possesses surrounding areas or spatial environments extending to various distances.

The materials necessary for human existence on earth (foodstuffs, fuel, clothing etc.) are taken from the ecosystem, the earth's crust or its bodies of water, and processed for use. Foodstuffs are produced by agricultural units on completely different soils and in widely varying climatic zones. Agricultural implements are made of material which is available only in certain areas of the earth's surface. In most cases, processing takes place in different locations depending often on the infrastructure, but primarily in the urban areas of highly industrialised countries. Modern global trade links the areas producing raw materials with those where manufacturing is carried out, as well as producers and consumers all over the world. So-called globalisation builds upon existing population structures. In this way, the ecumene becomes a unit, although the regionally varying degree of specialisation has to be taken into account (contrasts industrial and developing countries). The resulting problems of inequality (shown in the exploitation of the weak) are not discussed here.

2.5.4. Other examples

Hierarchies are ubiquitous. Through hierarchies, the production of the non-equilibrium systems can be co-ordinated, the processes, i.e. the flows of energy can be controlled and the energetic resources of the environment to a great extent optimally exploited.

Mankind as a species and mankind as a society:

In the course of the cultural evolution, mankind as a society has developed structurally out of mankind as a species (see section 2.5.3.2). Thus, the energy in the ecumene can be obtained much more efficiently. Indeed, the extraordinary exponential growth of the population and the increase in life expectancy and living standards prove that mankind is learning to exploit the resources of the inferior environment much better.

Tab.4:
Primary und secondary populations in mankind

Primary populations	Secondary Ppopulations
Mankind as population	
Small cultural population	Large cultural population
Tribe, people	Population of state
Ethnic group	City-umland-population
Local group, community	Community
Family	Organisate
Individual	

The differentiation of the flow of energy and the differentiation in hierarchically arranged populations is essential for this. A hierarchy has also formed in mankind as a species, probably at an earlier phase than mankind as a society, but then parallel to it. Thus, we distinguish between "primary populations", in which mankind's biotic concerns (i.e. those affecting its existence) are regulated, and "secondary populations", with their socio-economical tasks within the context of mankind as a society. Everyone (by working beings) are directly or indirectly involved in mankind as a society, and as a biotic being in mankind as a species (see tab. 4).

Hierarchy of the living world:

Mankind as a species is itself part of the global ecosystem and as such embedded in a vertical flow of information and energy. Taxonomically, mankind is one species among many. It may be assumed that hierarchical structures have also formed among other species, which are admittedly much less differentiated than in the case of mankind.

Perhaps the global ecosystem also structured itself as a hierarchical system for reasons of control. After all, mankind as a species is part of this system and as such, embedded in its vertical flow of information and energy. Then it would be possible to assign the non-equilibrium systems in the hierarchical levels to the tasks in the same way as the populations to mankind as a society. The following is an attempt to do so (see 2001):

1st level: Perception of the environment. The living beings perceive the advantages and disadvantages of the environment to their own advantage. Carrier: the living world as a whole, task: perception.
2nd level: Decision on the type of exploitation of the environment. The plant and animal kingdoms define themselves as antagonists through their position in the flow of energy (see section 2.6.2). Their independent existence is dictated by this. Carrier: the kingdoms, task: determination.
3rd level: Control of the flows of information and energy. The absorption of nutrients and reproduction are specified by the fact that living beings belong to certain species. This permits a control of the vital processes of life. Carrier: the species, task: regulation.
4th level: Contact with the inorganic inferior environment, transition of flow of information to flow of energy. The living beings define themselves as independent objects in their environment and give the vital processes spatial order internally. Carrier: the organism, task: organisation.
5th level: Division of energy from the inferior environment in the system. The internal flow of information and energy involved in the metabolism is carried out by the organs. Carrier: the organs, task: dynamisation.
6th level: Transformation of energy into useful substances or products. The various (metabolic) products are manufactured

for the body in chemical working units by a process based on division of labour. Carrier: the cells, task: kinetisation.
7th level: Organic substance preserves life. The construction of organic substance and its release from the inorganic environment are controlled at molecular level. Carrier: the organic molecules, task: stabilisation.

In the hierarchy, the non-equilibrium systems are loosely distributed at the levels 1-3, but concentrated more compactly at the levels 5-7. The organism divides both partial areas of the hierarchy. The similarity with mankind as a society is apparent.

Each non-equilibrium system is securely bound into a hierarchy and possesses a defined task for this hierarchy. In the hierarchical systems, non-equilibrium systems are created structurally. One has to assume that hierarchical structures have also formed in the inorganic world, e.g. in the creation of the macro- and microcosmos (see section 2.6.3.). However, the hierarchies are normally much less differentiated, i.e. at the various levels several tasks have to be resolved in the vertical process sequence.

2.6. Autopoietic processes and Universal system

2.6.1. A farm

Although it was part of the secondary sector of economy, the textile mill was in close contact with the natural resources of the earth in several respects. The buildings, as earthbound artefacts, were constructed of natural materials, bricks, mortar, lime, wood etc. The machines were of iron, the driving belts of leather. The company processed the natural fibre of cotton. All these materials were already the products of organisates in the mining, quarrying, iron-working, agriculture and forestry industries. For the most part, these organisates had taken their raw materials from the natural resources provided by the ecosystem and its mineral environment.

These organisates were part of the primary sector of economy which intervenes in the natural systems of our planet to the benefit of mankind. This brings us to a new field of study which can be illustrated most clearly using the example of an agricultural organisate, i.e. a farm of the kind familiar to most of us (see section 2.4.4.1).

By tilling the soil, fertilising it, selecting crop varieties, breeding and fattening animals, the farmer tries to adapt part of the inferior environment as far as possible to fit his own purposes. Crop plants and domestic animals are part of the ecosystem. In the course of cultural evolution, they have been bred gradually from originally wild animals and adapted to fulfil the needs of mankind. Compared to these, other species of plant and animal (rabbit, deer, martin etc.) are of less importance. Others are a hindrance to the work of the farmer (e.g. weeds) and are controlled or even exterminated as pests. In this way, the ecosystem has undergone dramatic change. It has been turned into a kind of canopy which secures the livelihood of the farmer, if he is able to use it and control it to his advantage.

Through his work, the farmer controls the cultivation of crop plants and animals according to the scientific knowledge available to him. He benefits from the fact that human beings depend on these plants and animals for their nourishment. He encourages the biotic processes although he cannot change them as such. He intervenes in these natural processes to a certain extent, without being able to reverse them. That living creatures create themselves, that plants are eaten by animals, that animals are born, grow, reproduce and die - all these are beyond the influence of the farmer and the whole of mankind as a society.

Thus, the farm is subject to constraints which originate outside the day-to-day routine of work. They affect the running of the organisate and its produce as well as the life of the people. These processes are "autopoietic processes" (MATURANA and VARELA 1984/87; MATURANA 1998).

2.6.2. General considerations

The farmer sows the crop plants (e.g. cereals and turnips) or plants them in the ground as tubers or seedlings (e.g. potatoes) (see section 2.3.4.1). From the soil, these obtain the substances required by their metabolisms for growth. By fertilising the soil, the farmer provides any substances which may be absent or which stimulate the activity of the microorganisms living there (loosening of the soil, production of detritus and minerals etc.).

The plants provide the cultivator with his yield. As with all autotrophic plants, they are perfectly "designed" for their purpose. They have extensive root systems by means of which they obtain nutrients and water from the soil. Through tubular cells, these substances are conveyed upwards through the equally extensive system of stem, shoots and leaves (cormophytes). The water is sucked upwards by capillary action caused by the evaporation deficit in the leaves. Through small valves or pits, the leaves extract carbon dioxide from the atmosphere and release oxygen. In the leaves, sometimes even in the shoots, the nutrients are converted chemically into organic nutrients. In the individual cells, the pigment chlorophyl absorbs light from the sun and transforms it into chemical energy.

The plants spread through reproduction mechanisms (e.g. airborne pollen, pollination by insects) and the transport of seeds by wind, water and animals. They form populations ("area systems"; MÜLLER 1981) to assure their survival. They create their habitat and their place in the food chain i.e. their ecological niche. In the course of evolution, the plants have become increasingly differentiated by adapting to environmental conditions. A multiplicity of different species arose of which the farmer makes use of only a tiny fraction.

Besides the autotrophic plants, there are also heterotrophic plants which exist as parasites and obtain their nutrients from the host plant. Some plants exist in a symbiosis with others.

The vegetable matter produced by the farm forms the basis for the nourishment of animals (cattle, horses, pigs, poultry). Thus, the farmer repeats in a controlled manner the same processes as take place in the ecosystem as a whole (see fig. 33). The autotrophic plants serve as nourishment for the

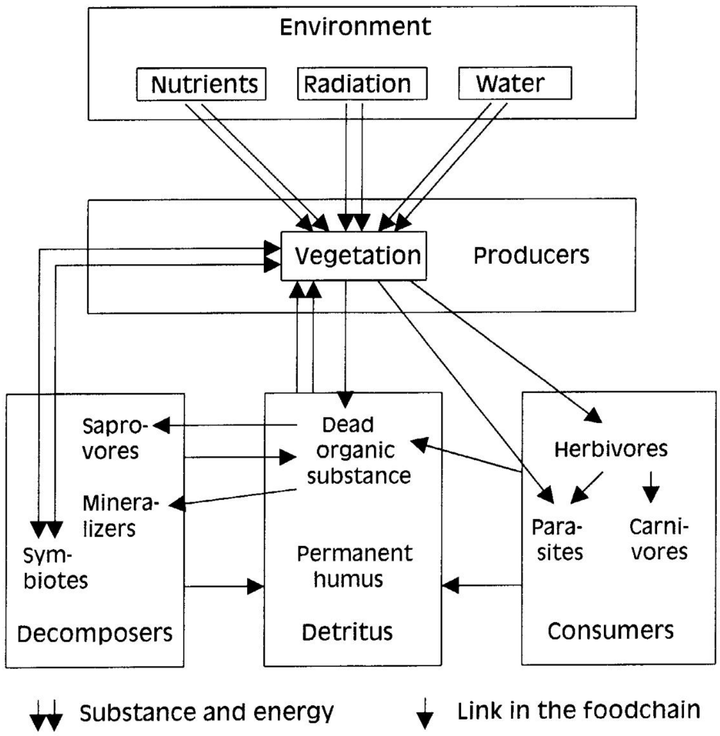


Fig. 33:
*The basic structure of the food chain in the ecosys*tem.
The autotrophic organisms (in particular the plants) thrive on mineral nutrients through radiation energy and water. They are the producers in the ecosystem. These in turn are a source of food for herbivores, and the herbivores in their turn for the carnivores and parasites as consumers. Some animals and plants live in a symbiosis, i.e. they benefit from one another (e.g. lichens). Living organisms disintegrate to form detritus which serves as humus or a source of nourishment for saprophytes, which contribute to its further disintegration. The mineralisers (e.g. bacteria) then reduce these substances to their inorganic constituents, some of which return to the food chain as nutrients for plants.
(Source: ELLENBERG 1973; KLUG and LANG 1983. See "Notes on the figures").

heterotrophic animals. In the ecosystem, the plants are the "producers", the animals the "consumers". When the animals feed, the cell structure, i.e. the shape of the plants, is destroyed. The organic substance is absorbed by the body, digested, i.e. prepared mechanically and then decomposed chemically by the body and, as far as possible reabsorbed materially and energetically. The process of digestion involves a number of different organs. The oxygen present in the atmosphere or water is required by the metabolism and is absorbed by other organs such as lungs or gills. Once inside the body, the substances are conveyed to the organs which require them and transform them by the circulation system. The gases which are not required for the metabolic process and the creation of organic substance (e.g. carbon dioxide) are returned to the atmosphere, while the remaining substances are excreted and decomposed by micro-organisms in the soil or water along with dead vegetable and animal matter and made available again in this way to the ecological cycle.

Unlike the plants, animals normally have the ability to move, can orient themselves in space by means of sensory organs and create their living space and habitat along with others. Thus, they are able to find the plants they require for nourishment and as well as the necessary sources of water. Man has proved to be particularly skilled at these activities. Mankind as a species has created mankind as a society which has become extremely skilful at exploiting the ecosystem as a source of energy (see section 2.5.4).

As the elements of the ecosystem the living creatures shape and maintain themselves as "autopoietic systems" (MATURANA and VARELA, see above) by generating themselves by means of cell growth. They are their own products. At the same time, they form the raw materials for other living creatures. The ecosystem consists of a large number of area systems, each of which occupies its own ecological niche. The living creatures maintain their species and their area systems by means of specific reproductive mechanisms, in addition to which they create nourishment (energy) for other organisms and area systems in their ecological niches. In this way, the energy stored in the organisms is distributed throughout the ecosystem. Some of the food chains which have formed are very extensive and linked with one another by cycles. This means that it is difficult to trace the flows of energy in detail. But it is this complexity of the ecosystem which demonstrates the effort made by living creatures to use the energy available to them as fully as possible.

The ecosystem and its living creatures as autopoietic systems belong to the 6th or highest level of complexity. They presuppose the existence of the universal system.

2.6.3. The model of the universal system in the mesocosmos

2.6.3.1. The living creatures

In the 3 preceding stages of complexity, the systems (flow-equilibrium, non-equilibrium and hierarchical systems) and their elements appear as structures which maintain themselves through the processes (flows of information and energy) but also represent the framework for these processes. The ecosystems too maintain themselves through flows of information and energy, through processes between demand and supply. However here, the living creatures are themselves drawn into the process as the elements of the systems themselves, are transformed in the course of the process and eventually destroyed to form the substance needed to build up new life.

The living creatures maintain their existence through constant renewal of their cells. Within the cells, the substances supplied to the creature are chemically transformed. MATURANA and VARELA had this process of renewal in mind when they formulated the concept of the autopoietic systems at a time when system research had actually developed a different perspective (see section 2.3.4.1). While this attempted to identify the flows of energy and the principles of systems by more and more refined methods, the authors attributed more importance to the process of self-renewal. Seen from this point of view, autopoietic systems are distinguished by the fact that they create themselves, that they represent their own product.

In our context, it should be regarded as particularly significant that two levels are concerned here - the level of the organisms and that of the cells. In the case of more highly developed creatures, the level of the organs intervenes. One may take the view that the organisms are the systems, the organs the sub-systems and the cells the elements. The cells create the substance, thereby allowing the organisms to supply themselves internally with energy. The organisms have a shape which makes it possible for them to procure the required energy externally. Their form allows them to adapt themselves in such a way to the energetic environment in the ecosystem that the flow of energy is optimised. However, the self-organisation of living creatures cannot take place through a simple re-arrangement of the elements, i.e. the cells, in the same way as it does with the non-equilibrium systems, because organisms have a strictly prescribed internal order.

Living creatures have only a limited life span and are themselves part of the food (energy) cycle. In this way living creatures organise themselves from one generation to another. The necessary information is stored in the cell nuclei (DNA) and passed from one generation to another through the reproductive mechanisms. In the course of evolution, improvements in self-organisation can take place (via mutation) in response to environmental conditions.

The living creatures occupy a position intervening between macro and microcosmos, where the organisms of the higher plants and animals refer to the macro-cosmos and the micro-organisms and the cells on the other hand to the micro-cosmos.

2.6.3.2. The inorganic environment

In the last resort, the energy required for the life processes is taken from the inorganic environment. On the one hand, this surrounds the global ecosystem and its life forms in the shape of rocks, water and air, and therefore represents the superior environment. The soil conditions, water and weather conditions make specific requirements on the adaptation of the life forms and populations of the ecosystem and have in the past significantly affected the process of evolution. Through their form, living creatures and life in general are able to remove energy particularly efficiently from the inorganic environment as the superior environment.

On the other hand, the inorganic environment as inferior environment supplies, in the form of molecules, the substances which are absorbed by living creatures and which serve as the chemically transformable raw material for the food chain. It includes water and air as essential raw materials for all living beings. The absorption and release of water are precisely controlled by the plant, as is the exchange of gas in adaptation to the atmosphere. The soil is of particular importance. Its ecosystem is a system with a highly complex structure. Plant life absorbs the substances, whereas the rocks, the most important sources are destroyed thereby releasing their nutrients. The process is aided by atmospheric phenomena (rain, wind, snow, frost, temperature change etc.) as well as the many forms of life in the soil, the microbe populations, fungi, larvae, worms, moles etc. which prepare the chemical substances originating in the rocks, thereby forming soil. On the other hand, organic detritus is decomposed down to its constituents, i.e. down to molecular level. Almost all the chemical substances required are dissolved in water, and thus prepared for the construction of organic material.

The living creatures for their part also help to shape their inorganic environment. Mankind interferes (on the whole, negatively) in the workings of the global ecosystem. Through his influence, not only the soil and water are damaged (by soil erosion, "desertification", pollution etc.), but also the atmosphere through emission of toxic substances.

2.6.3.3. The sphere structure

This short description of the structure of the ecosystem allows three different levels of being to be distinguished which we will term "spheres". Firstly, the global ecosystem appears in this system as the "biosphere". It is surrounded on the one hand by the second of these, the "chemosphere" (or "chemical sphere") consisting of the rock, water and air "envelopes", and on the other by the third, the "molecular sphere", which is made up of components from the chemosphere.

Their substantial consistency and the (spatial) order of magnitude of the non-equilibrium systems forming them, separate the flows of information and energy of the spheres from one another (see fig. 34). The compartments of the

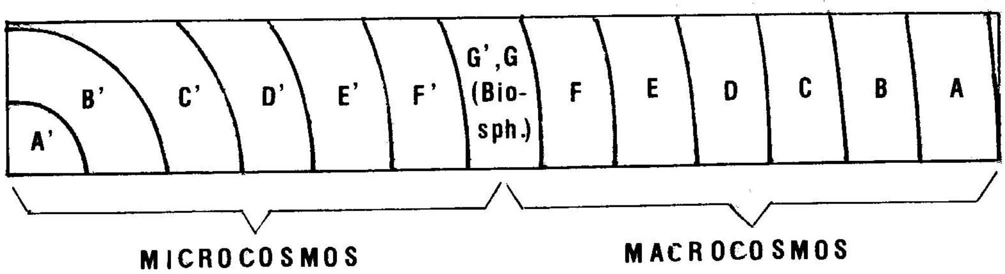


Fig. 34: *The Spheres in the macro- and microcosmos*.
In the frame of the mesocosmos und its environments we distinguish:
D = Sphere of the solar system,
E = Sphere of the planets,
F = Chemosphere,
G = Biosphere (organisms),
G'= Biosphere (cells),
F'= Molecular sphere,
E'= Sphere of the ions, and
D'= Sphere of the atoms.

chemical sphere belong to the macrocosmos. The molecules (i.e. the molecular sphere) on the other hand, are part of the microcosmos. In its magnitude, the biosphere intervenes between these two spheres and therefore between the macro and the microcosmos. As already stated above (see section 2.6.3.1), the higher forms of life should be assigned to the macrocosmos and the micro-organisms and cells to the microcosmos. In the course of evolution, living creatures have acquired a shape which is adapted to the conditions of the chemosphere. In the cells of the living creatures, the substances derived from the molecular sphere are transformed, i.e. given the composition suitable for the living creatures.

Perhaps one can deduce that the creation of form takes place from the (superior) systems (organisms) to the (inferior) elements (cells) from above in a downward direction, and the formation of substance in the opposite direction from the elements (cells) to the systems (organisms), i.e. from below in an upward direction. Perhaps it is possible to deduce further that the task of the systems in the macrocosmos is the creation of form, and of those of the microcosmos the formation of substance.

Broadly speaking, the creation of form may be interpreted as the formation of a boundary between two substances, i.e. as a separation of these substances. The creation of form therefore means the shaping of space, because space receives its shape through the forming of substance. With systems however, the acquisition of space also includes the insubstantial, inasmuch as this is thematically established by the system-element relationship. In the universal system, the self-regulating spheres of influence disappear (see section 2.5.3.4) and are replaced by strictly controlled intervening spaces, i.e. by thematically aligned and controlled spaces which are substance-free.

If we now attempt to place the spheres of the macro and microcosmos in one scale, it must be remembered that the reliability of this statement decreases as the distance from the mesocosmos (the order of magnitude assigned to geographers) increases.

The biosphere, which, in this model, occupies a position in the system intervening between macro and microcosmos (as noted above), need no longer concern us here. The second sphere in the macrocosmos (also previously noted) is occupied by the chemosphere, and the second sphere in the microcosmos by the molecular sphere. The molecules therefore appear as the elements of the chemosphere. As with the biosphere, one may deduce that the systems of the molecular sphere (the molecules) create the substances for the systems of the chemosphere while the systems of the chemosphere create the forms for the systems of the molecular sphere. In the above-mentioned compartments of the chemosphere, flow-equilibrium systems and non-equilibrium systems (currents, layers, air masses, eddies, waves etc.) are constantly forming and disintegrating depending on combination. These systems are generally unstable, but durable substances (gases, liquids, rocks) in many different forms and compositions come into being. In the microcosmos, the molecules are created and transformed. There is an almost unlimited variety of shapes and materials. The processes of transformation are absolutely dominant and unique in the spheres.

If we add more spheres to these, it becomes more difficult to make definite statements, as these can only be supported by partial observations which are interpreted here in the context of the model:

In the third spheres of the macro and microcosmos, durable systems, unlike the systems of the chemosphere, transform energy. As a representative of the "planetary sphere", the planet earth adds a new phenomenon, that of rotation. Internally, this produces a dynamo effect, i.e. the electrically charged positive and negative particles are separated from one another at the micro-level ("sphere of ions"). In the macrocosmos, the "solar sphere" represents the forth sphere. It is divided into the central star (the sun), the planets and the asteroid belt. It is here that the matter in the macrocosmos is concentrated and separated. The greater part of the mass of this system is concentrated in the sun. In the same way, passing down the hierarchy into the microcosmos, the "sphere of the atoms" adjoins. If we continue to pursue this model, it is in direct association with the sphere of the solar system, not only through the shape of its systems (if we take Bohr's model as applying to the atoms). The atoms are also created in the solar system. The conditions for their formation alter from the centre (of the sun) towards the edge of the solar system, with the result that (in line with the periodic system of the elements) completely different atoms come into being.

The hierarchy of the spheres of the macro and microcosmos which are more distant from the mesocosmos will be discussed no further here. This is better left to the experts. However, perhaps we are in a position to formulate a few more general considerations with all due caution:
1) The spheres are screened off from other spheres through the substantial consistency, structural peculiarity and order of magnitude of the systems constituting them. They are energetic interaction spaces with laws of their own. They convert energy to substances and substances to energy, structure and form themselves into matter. For the spheres, the flows of information and energy are specific.
2) The systems making up the spheres in the macrocosmos (living creatures, eddies of the chemosphere (?), planets and solar systems) are associated with the systems of the correlating spheres in the microcosmos (cells, molecules, ions and atoms) by the relationship of system to element (see fig. 35). The systems are not only non-equilibrium systems, but also autopoietic systems (see section 2.6.2). These systems also create themselves materially. They are their own product, together with their counterpart in the correlated sphere of the macro or microcosmos. For example, living creatures depend on the material production of their cells (they procure the energy and matter from the inferior environment), while, on the other hand, the cells depend on receiving their shape from the living creatures (they exploit the possibilities of the superior environment by adapting their shape). This may also happen in a similar way with the inorganic spheres. Living

creatures require DNA in order to pass their essential characteristics to the next generation, as they themselves are involved in the food-energy cycle.

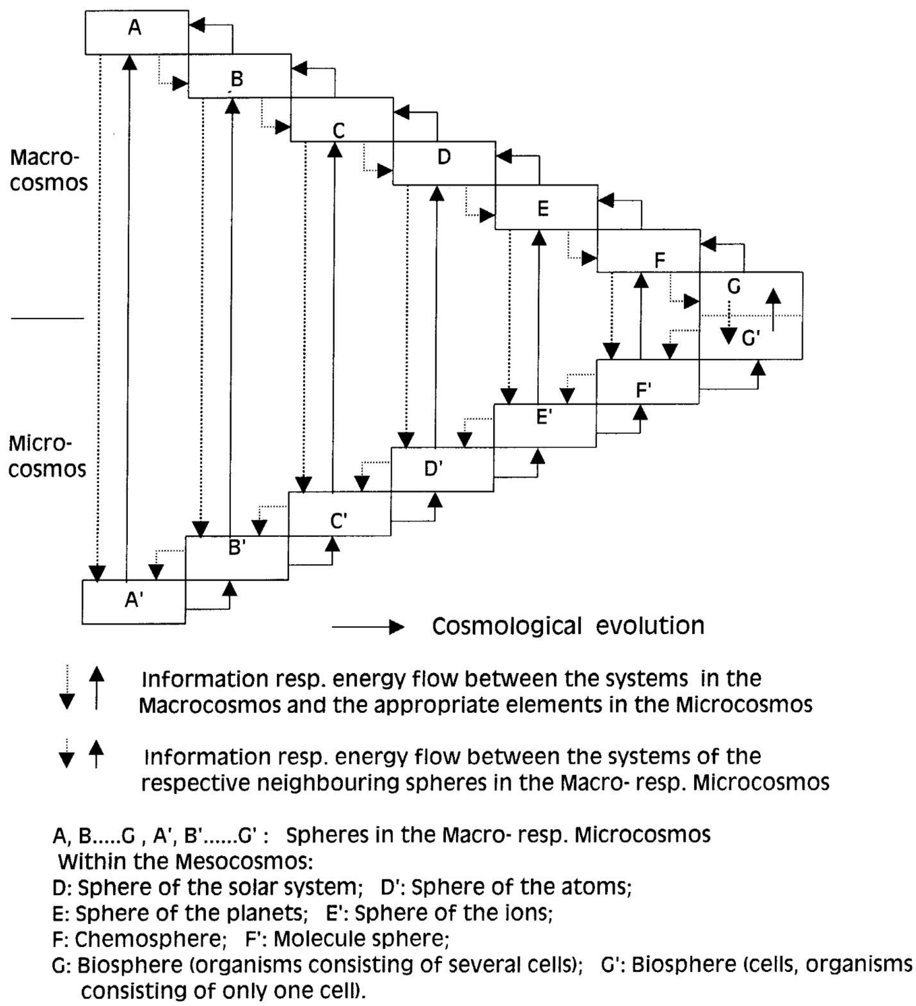


Fig. 35:
The spheres of the macro and microcosmos.
From the point of view of the process theory in the mesocosmos, the spheres of the macro and microcosmos may appear as follows with regard to the linking of their systems:
Horizontally linked, i.e. between adjacent spheres, the flow of information (or the formation of form and space) travels from the higher to the next lower sphere, while the flow of energy (or the formation of substance) proceeds from the lower to the next higher sphere. At the same time, the systems of the spheres diametrically opposite one another (e.g. the organisms G and cells G' of the biosphere, the systems of the chemosphere F and those of the molecular sphere F') are determined by the relationship of system to elements, i.e. the relationship of the systems in the macrocosmos to those in the microcosmos is that of order - obedience. Dotted arrows indicate the flow of information (formation of form and space) and the continuous arrows that of energy (creation of substance).
Perhaps cosmological evolution took place from left to right so that the biosphere was formed at the end of the development.

3) The individual autopoietic systems are encompassed by the autopoietic systems in the next higher sphere of the hierarchy, and they themselves encompass the autopoietic systems of the inferior spheres. In this way, a space is created which is similar in structure to the skins of an onion.
4) It is not possible to make any definite statement here on how these spaces came into being in the course of cosmic evolution, on the pattern and periodisation of the formation of matter and space, and on their similarities and differences with regard to biotic and cultural evolution.

3. Interpretation

3.1. Review of results

In the previous section (see section 2), we described the processes and systems in their environments using a weaving mill as our example. The processes take the form of flows of information and energy. Complexity is the entwining of the process sequences. Accurate analysis is possible only by tracing these sequences individually, not by studying the system with its complicated links and interconnections. The sequences on the other hand are thematically determined, temporally arranged, hierarchically controlled and spatially organised.

The systems are persisting structures. They are created by the processes, and these in turn are created by the systems. To permit the transfer of energy and the stabilisation of the processes, the processes and systems must be concretised by means of a substance.

The transfer takes place by means of movement of the solids, the elements, from undifferentiated substance or (more precisely adapted and given the form) of generated products. The "carriers" concretise the systems which execute the actions and processes and give them stability.

Six levels of complexity can be distinguished due to their composition, their internal structure and their relation to their environment:

1st level of complexity (see section 2.1): The movement of a solidum is occasioned and controlled by its environment. At the stimulus, it receives energy and returns it to the environment (perhaps at a different place). At this level of complexity, the differentiation of the temporal sequence of events is not yet a matter of discussion. Movement is the simplest form of energy transfer.

2nd level of complexity (see section 2.2): The movement project and the equilibrium system are composed of many movements and solida. They are occasioned and controlled by their environment. During the course of the project, energy is absorbed and again released. This takes place in a certain sequence in time. During the course of the process, the elements adapt to the environmental conditions. In this way, they try to maintain themselves in an energetic equilibrium. From an energetic point of view, the system is the sum of its elements. Equilibrium systems order themselves.

3rd level of complexity (see section 2.3): The flow process and the flow equilibrium system are composed of many movement projects and equilibrium systems. They are stimulated by the environment, but the energy is taken from another environment by the system. We distinguish between the energy-demanding superior environment and the energy-supplying inferior environment, between the flow of information and the flow of energy. This makes the transfer process non-linear. Internally, the hierarchy of bonding levels is created in the course of the flow of information, and utilised by the flow of energy. The energy is distributed according to the demand. Whereas at the first and second levels of complexity, it is the environments which determine what takes place in the system, in this case the energetic environment is altered by the system. The flow process and the flow-equilibrium system regulate themselves through feedback.

4th level of complexity (see section 2.4): The conversion process and the non-equilibrium system are composed of many flow processes and flow-equilibrium systems. These are spatially arranged and interlinked with one another as well as with the systems supplying the information and energy in the spatial environment. At the same time, the temporal sequence is expanded and ordered so that the internal flow of information and energy can be controlled in time. Processes consisting of several parts are created in a specifically defined arrangement, whereby the flow processes and flow-equilibrium systems are coupled and can control certain tasks for the whole. In this way, it becomes possible to manufacture products which are assembled precisely in accordance with demand (induction process) and supply them to the demanding environment. Besides, with a certain delay, their own system is shaped in accordance with the requirements identified in the induction process (reaction process). In this way, the conversion process and the non-equilibrium system organise themselves.

5th level of complexity (see section 2.5): The hierarchic process and the hierarchic system are composed of many conversion processes and non-equilibrium systems. These have certain tasks to fulfil for the whole, i.e. to manufacture well defined immaterial and material products. The conversion processes and non-equilibrium systems are bundled at the appropriate hierarchical level. The cohesion of the hierarchical system is guaranteed by a strict order-obedience relationship. The non-equilibrium systems occupying lower positions in the hierarchy must produce for the superior non-equilibrium systems. Accordingly, the processes of the inferior systems have a shorter duration (on average by a factor of 10). By means of selection, unsuitable systems are discarded into the inferior hierarchic levels, or new systems are created if these are required. Thus, the hierarchical process and the hierarchical system not only control themselves, but also create themselves structurally.

6th level of complexity (see section 2.6): The universal process and the universal system (examined here in the mesocosmos only), are composed of many hierarchical processes and hierarchical systems. Here, matter is arranged hierarchically and ordered spatially in spheres. In this way, the systems of the superior spheres encompass those of the inferior spheres. This results in 7 spheres each in the macro and microcosmos, which are joined together in the biosphere. The systems of the inter-related spheres in the macro and microcosmos (e.g. the molecular and chemical spheres) are joined together by a system-element relationship. The universe and the systems constructing it control each-other completely. In addition, they create themselves materially (autopoiesis).

3.2. Tentative explanation

The processes and systems discussed represent archetypes. Any phenomenon, any place in the universe belongs to all types of systems or processes simultaneously. We will now attempt to put the results into context, and will proceed in four steps:
1) Reduction of the process and system types of the different levels of complexity to their basic structure and plotting in a system of co-ordinates (section 3.2.1).
2) Representation of the process of emergence joining the process and system types of the various levels of complexity together (section 3.2.2).
3) Charting the course of the processes at the different levels of complexity in detail (section 3.2.3).
4) Interpretation of the "mechanics" behind the processes (section 3.2.4).

3.2.1. Basic structure of types of processes and systems

First of all, we must attempt to reduce the processes to the essentials necessary for our purposes, i.e. to those principles which make all the processes and system types characterising the levels of complexity comparable and therefore distinguishable and capable of being linked. The principal unit of each process is the "basic process", which is composed of 4 stages. In more complex systems, the basic processes join up to form sequences of different kinds. In this way, they can be comprehended as modules affecting the entire process and system-related structure of reality.

In order to obtain a formal framework, we will use the co-ordinate system (see fig. 36), which we will call the "system co-ordinate system". (This distinction is necessary, because we will make the acquaintance of other co-ordinate systems - emergence and train co-oordinate system - later, sections 3.2.2 and 3.2.4). We now allow the process to pass through the quadrants in succession. The starting point in each case is the f(x) quadrant. The process takes us either in a clockwise (mathematically negative) or anticlockwise (mathematically positive) direction through the co-ordinate system.

1st level of complexity (movement, solidum):

The solidum and the simple movement are not yet complex. However they are the first stage to be passed through on the way to complexity. At this level, we are concerned only with the transfer of energy in the solidum, the internal relationship of cause and effect (see section 2.1). The

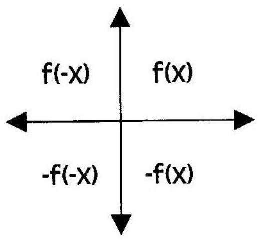


Fig. 36:
Model of a coordinate system.

process itself, the temporal sequence, is not yet under scrutiny. The Newtonian formulae quoted in section 2.1.3 do not describe the temporal sequence, the stages, of this movement process, but link the beginning and the end to one another and describe the relationship of the parameters to one another, which lead to the result.

For us, it is of importance that the structural symmetry is described here. The flow of energy takes place in the pattern of action and reaction. According to the arrangement in the internal system co-ordinate system (which is passed through in

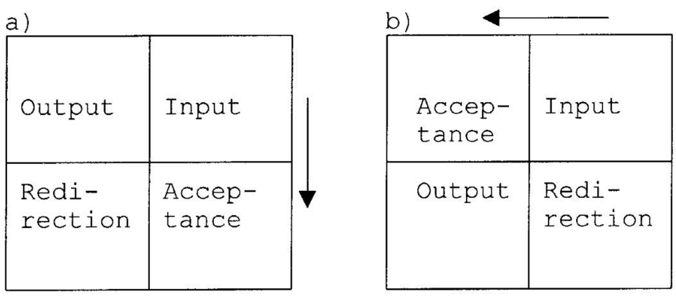


Fig. 37:
The processes in the coordinate system with the 4 stages input - acceptance - redirection - output.
a) Course of process in a clockwise (right-hand) oriented system,
b) Course of process in a anti clockwise (left-hand) oriented system.

clockwise direction), this involves a double counterbalance (see fig. 37): in vertical direction (solidum-environment) [+y] against [-y]; in horizontal direction (inwards-outwards) [+x] against [-x]. The sequence of the quadrants affected is:

1) Input [+y,+x]; 2) Acceptance [-y,+x]; 3) Redirection outwards [-y,-x]; 4) Output [+y,-x].

2nd level of complexity (movement project, equilibrium system):

At the second level of complexity, a structure begins to take shape: a system as a whole is composed of elements. Both time and space are separated from the transfer of energy, i.e. the transfer of energy takes place spatially-temporally in stages, thereby changing the cause and effect relationship into a process. As the movement project progresses, the elements can adjust to the environmental conditions, thereby remaining in energetic equilibrium. An equilibrium system forms. The process first concerns the whole and then the parts. The stimulus comes from the horizontal, i.e. the temporal and spatial environment. Considered geometrically, the system does not change its size in the course of the process. As in a tube, the first two stages are directed inwards (towards the middle of the tube) and the two following ones outwards. This means that in the co-ordinate system, the two [+y] quadrants (= system as whole) are passed through first, then the two [-y] quadrants (= elements). The direction is therefore anti-clockwise. The system orders itself in this way:

[f(x)]: Input of impulse (absolute value) from the spatially and temporally preceding environment. The energy is distributed according to the structure of the system. The fact that the elements must contact one another in order to absorb energy, must be taken into account.
[f(-x)]: Acceptance of the impulse: Only as much energy is absorbed as free capacity is available in the system, i.e. the quantity of the actual energy absorption is determined in relation to the possible energy absorption (relative value). Up to here, the process is directed inwards. The outwardly directed part of the process now follows.
[-f(-x)]: Re-direction from the whole of the system to the quantity of the elements and from the inwardly to the outwardly directed flow of energy. The relative value is assigned to the individual elements, step by step. Reversion of the mathematical equation relating to f(x).
[-f(x)]: Output. The resulting absolute value is relativised in comparison to the succeeding environment to which the energy is passed on. The elements as energy carriers are brought into contact with a new system in the succeeding environment.

3rd level of complexity (flow process, flow equilibrium system):

At the 3rd level of complexity, the energy from the environment is integrated into the system. In the processes, the vertical component comes to the fore (demand against supply). This means that the co-ordinate system is run through in clockwise direction.

In the flow of information from the energy-demanding superior environment to the energy supplying inferior environment, the system is structured, i.e. the hierarchy of the bonding levels is built up. The two upper bonding levels representing the system as a whole are in contact with the superior environment, while the two lower bonding levels representing the elements differentiating the system, intervene towards the inferior environment (see section 2.3.3). With every bonding level from top to bottom, the flow of demand or information in the co-ordinate system receives a new characteristic:

[f(x)], Input (1st bonding level): The quantity of demand input from the superior environment is braked by a counterforce which is (limited by the size of the system).
[-f(x)], Acceptance (2nd bonding level): This quadrant is the intermediary to the elements. The amount of demand is limited by the counter tendency resulting from the limited number of elements, i.e. capacity of the system.
The two quadrants are affected by the superior environment. The following two quadrants lead to the inferior energy-supplying environment:
[-f(-x)], Redirection (3rd bonding level): The quantity of demand taken from the superior environment must be passed on by the elements towards the inferior environment.
[f(-x)], Output (4th bonding level): At the lower end of the bonding levels, the demand of the system is confronted with the energy supply from the inferior environment. The speed and extent of the absorption of energy into the system is determined in interplay by the inferior environment.

The energy now flows in the opposite direction from the inferior environment against the flow of information (demand), i.e. through the 4th, 3rd, 2nd, and 1st bonding levels prepared in the flow of information, to the demanding superior environment.

Through the relation between the flow of information and the flow of energy, the system and the energetic (superior and inferior) environment are linked to one another. The feedback at the point of junction between system and superior environment, where demand and supply are compared, permits the self-regulation of the system. Oscillations may occur.

4th level of complexity (conversion process, non-equilibrium system:

At the 4th level of compexity, the temporal process is also specified and arranged in a hierarchy of 4 process levels. Now the differentiation of the temporal process dominates with a total of 16 (or 13 through overlapping) task process stages, and at the inferior level 64 control and 256 elementary process stages.

In this way, the non-equilibrium system is also anchored horizontally (temporally) in the environment, or, seen from a different angle, the non-equilibrium system has annexed a part of the temporal environment, i.e. taken over control of it. In the process hierarchy in the system, the 4-stage sequence of the main process (see section 2.4.3.2) appears above, at the border to the superior environment. The co-ordinate system is again passed through in horizontal direction (anti-clockwise).

[f(x)], Adoption: The demand (information) is entered as a stimulus from the market, passed downwards through the 4 process levels and processed according to the system structure.
[f(-x)], Production: The energy is absorbed from the inferior environment according to the capacity available, and passed upwards through the 4 process levels and in so doing is processed into the products demanded.
[-f(-x)], Reception: Here, the market-related flow of information and energy turns into the system itself, during which the 4 process levels again have to be passed through. The system recognises the necessity of adapting to the circumstances of the market (environment).
[-f(x)], Reproduction: The system re-shapes itself as specified by reception (self organisation).

5th level of complexity (hierarchical process, hierarchical system):

At the 5th level of complexity, another vertical alignment takes place. The energetic relationship of demand and supply has to be distinguished from the hierarchical order-obedience relationship which serves the purposes of control. This involves clockwise passage through the co-ordinate system:
[f(x)]: The stimulus reaches the uppermost hierarchical level (on our example mankind as a population) in the system from the energetic and hierarchical environment (in our example mankind as a species). It is processed by the non-equilibrium systems at the 4 upper hierarchical levels.
At the 4th hierarchical level (in our example at the level of the city-umland populations), contact is made with the energetically inferior environment (the ecumene) to obtain sufficient energy for production.
[-f(x)]: The non-equilibrium systems of the 4 lower hierarchical levels assume the implementation, i.e. the conversion of the energy into products and supply this to the energetically superior environment (in our example mankind as species) at the lowest hierarchical level (the individuals).

In the order-obedience relationship, the order moves hierarchically from top to bottom to the elements, and the obedience from bottom to top. In this way, the entire system is hierarchically controlled.

The reaction process with its stages of reception [-f(-x)] und reproduction [-f(x)] is not conducted as an independent continuous part-process as with the non-equilibrium systems. Instead, the structural self-organisation in the non-equilibrium systems takes place at the hierarchical levels. Its self-renewal occurs by means of selection based on the signals which the market and the superior populations of the hierarchical system send out. This also includes the creation of new or the elimination of uncompetitive non-equilibrium systems by the hierarchical system.

Thus the hierarchical system is not only a unit controlling itself, but also one which creates itself structurally.

6th level of complexity (autopoietic processes, universal system):

The 6th level of complexity embraces the universe. Space and matter are created.

The universe encompasses all hierarchical systems, but also represents a succession of systems ordered hierarchically around one another, i.e. the spheres. We distinguish the macro and the microcosmos. According to our Process Theory, the macrocosmos is shaped by the induction process, the microcosmos by the reaction process. Both are completely fused together to form a system unit if we understand the autopoietic systems forming the microcosmos to be elements of the autopoietic systems forming the macrocosmos.

Thus, the induction and the reaction processes are structured in a hierarchically contrary way. The creation of substance in the microcosmos and the creation of space in the macrocosmos presuppose one another mutually. The passage through the co-ordinate system is counter-clockwise.

[f(x)], Adoption and [-f(-x)], Reception: In the 4 largest macrocosmic autopoietic units and the 4 smallest microcosmic autopoietic units the exchange of information and energy over greater distances possibly takes place through various kinds of radiation. This has not been discussed in detail here.

[f(-x)], Production and [-f(x)], Reproduction: In the inner autopoietic systems of the macrocosmos (solar system, planets, non-equilibrium systems of the chemosphere and organisms) and of the microcosmos (atoms, ions, molecules and cells of the organisms), shape and matter are formed. The exchange of information and energy takes place here in direct contact (by convection, catalysis etc.).

The universe therefore forms the framework within which the autopoietic systems create themselves materially.

3.2.2. The process of emergence

We have now gained an insight into the basic direction of the processes at the various levels of complexity. However, in order to understand the inter-relationships, it is necessary to take a closer look. It is not simply a case of one predominating process. On the contrary, complexity means that various types of process co-operate with one another and that the more simply structured processes are involved in the more complex ones.

We can progress further here if we treat the levels of complexity (characterised by the systems and processes forming them) as the divisions of a scale. We now have to establish which steps lead from one level of complexity to the next. Here, a new process takes effect which we will term the "emergence process", because it describes the way in which the structure of the systems receives new characteristics with each succeeding step - characteristics which are not explained by the components of the system itself. In order to lend shape to this process, a system of co-ordinates (the "emergence co-ordinate system") will also be used here. Each of the 4 quadrants represents a stage in this process. The numbers 1-2-3-4 therefore describe a basic process. This can be illustrated and simplified by using an example, the transition from the first (movement or solidum) to the second level of complexity (movement project or equilibrium system). Four different operations are necessary (see fig. 38):

1st operation: As shown above (see section 3.2.1), each single element (solidum resp. movement) can be represented by a system of coordinates. The first operation stands for an accumulation of these coordinate systems (see fig. 38a): "bundling".

2nd operation: The elements have to take their place in the whole. They are therefore re-arranged to form the new whole of the movement project ("alignment"; see fig. 38b). Thus, it is necessary to distinguish two levels, the whole and the elements. The whole must perform the movement projects, each part (i.e. element) its simple movements. This can be depicted

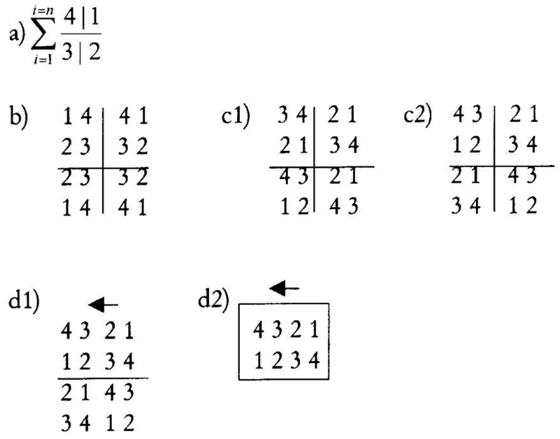


Fig. 38:
Diagram of the emergence process from the first to the second level of complexity.
a) Bundling: the movement-(action) project comprises n movements (action motions). The sum of the 4 parts of a movement (action motion) is shown. The numbers indicate the sequence.
b) Alignment: the bundled movements (action motions) are arranged in four groups for the new process. A new co-ordinate system (of the first order) is set up. In each quadrant, special co-ordinate systems appear for the bundled movements (action motions) as processes of the second degree.
c) Interlacement: the vertically aligned sequence is horizontally oriented. Description of the reversing operations:
1) Reversal of the smallest process units (in the quadrants) each containing four figures.
2) Re-arrangement of the figures in these process units depending on their position in the co-ordinate system of the first order.
d) Folding: the co-ordinate system is dissolved, the outlines of a movement project appear. Now the folding takes place. The lower part is folded behind the upper part by a hinge indicated by a horizontal stroke. The arrow shows the course of the process of the first order.
(Source: see "Notes on the figures").

by a comprehensive system of coordinates (1st rank) which symbolises the basic structure of the operations. The quadrants contain the partial (2nd rank) processes:
(1) The "input" of the stimulus from the environment in the system as a whole (quadrant [+x,+y]);
(2) the transfer of the stimulus or energy impulse to the elements ("acceptance") (quadrant [+x,-y]);
(3) the "redirection" of the energy impulse (quadrant [-x,-y]), and
(4) the "output" to the environment (quadrant [-x,+y]).

In addition the elements with their own movements must be considered. As all of them are subordinate to the system and involved in its movements, the movements are integrated in the whole. This can be represented by 2nd rank coordinate systems. In average, the individual elements participate in the four movements of the 1st rank system (i.e. the movement project or action project) symbolized in the quadrants of the overriding coordinate system. This can be represented in such a way that the subordinate coordinate systems (2^{nd} ranking systems) of the average single movements are inserted in each quadrant of the overriding (1^{st} ranking) system. Depending on their position in this coordinate system the subordinate process stages 1-2-3-4 are reflected at the abscissa and the ordinate.

3^{rd} operation: Now we are not only dealing with just a transfer of energy as in a simple movement. Instead, the temporal sequence has gained in importance. The elements in their own movements are connected with the system to form a process ("interlacement"). In our treatment of the solidum, the movement was represented in the coordinate system vertically (in clockwise direction). If we wish to comprehend the whole system and the elements in their temporal sequence, we must align them horizontally (in anti-clockwise direction). Thus the coordinate systems have to be inverted.

This has to take place in two operations (see fig.38 c1 and c2).
a) Firstly the numbers representing the individual stages of the movements in each of the four (2^{nd} rank) coordinate systems of the elements have to change their places, i.e. on the diagonal y=x. Then
b) these values are again converted according to their position in one of the 4 quadrants of the superior (1^{st} rank) coordinate system.

4^{th} operation: The last stage is the "folding" stage (see fig.38 d1 and d2), the coordinate systems are resolved. The horizontal process of the system (1^{st} rank process) appears as a sequence of 4 stages 1-2-3-4. As the uppermost line shows, it takes place from right to left. The (2^{nd} rank) element processes, however, are vertically ordered. The stabilisation of the process is represented by the actual process of "folding". The former y-negative quadrants (in fig. 38a these are shown below the line) are "folded" behind the former y-positive quadrants. With folding, the process becomes a system as a permanent structure.

Taken together, the stages described above - bundling, alignment, interlacement, folding - form the basic features of the emergence process. By structuring the coordinate systems at the system and element levels, symmetry (the structure) and asymmetry (the process) are brought into an order.

Here it becomes apparent how many individual steps are necessary. Everything has to be worked through. The necessity for completeness is apparent. In reality however, several phases are often closely packed into one stage.

The transitions between the other levels of complexity can be represented in basically the same way.

3.2.3. The course of processes in detail

Here, we can revert to the points discussed with reference to the emergence process and accept the description of the state of the interlaced and folded process sequence (as a result of the third and fourth stage of the emergence process). For all the levels of complexity, the other stages have already been described in detail by me (1999).

1^{st} level of complexity (movement, solidum):

We will depict the structure of energy transfer by means of a co-ordinate system (see section 3.2.1). In the [f(x)] quadrant, the impulse is entered ("input") and in the [-f(x)] quadrant it is accepted ("acceptance"). The "redirection" then takes place in the [-f(-x)] quadrant, and the "output" to the environment in the [f(-x)] quadrant. Thus, the [+x] quadrants contain the intake of the impulse, and the [-x] quadrants the delivery, the [+y] quadrants the contact area between environment and solid and the [-y] quadrants the system-internal impulse transfer (see fig. 39).

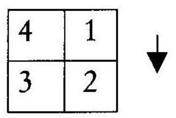


Fig. 39:
Scheme of the course of a movement.
(Source: see "Notes on the figures").

2^{nd} level of complexity (movement projects, equilibrium system):

As already shown above (see section 3.2.2), two levels, (the whole and the elements,) can already be distinguished in this level of complexity. The dominant process of the first order forming the whole takes place horizontally from right to left in stages 1-2-3-4 (see figs. 38, 40).

To each of these 4 stages are assigned the four stages of the processes of the second order. They are arranged vertically. The front view of the permanent process structure shows only 2 stages. The lower half should be conceived as being folded back, whereby the system is secured (contrary direction of the processes). One can now see that the individual processes of

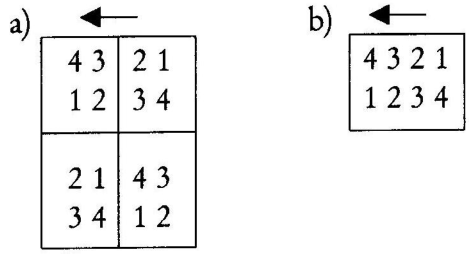


Fig. 40:
Scheme of the movement project.
in the interlacement stage,
in the folding stage.
(Source: see "Notes on the figures").

the second order take place in directions which are vertically opposite to one another.

Basically, the courses of the processes are always symmetrically arranged in the following stages as well. The sequence 1-2-3-4 is opposed by the sequence 4-3-2-1 (contrary course, see section 2.1.3). On the other hand, the process actually being gone through in each case is asymmetric per se. In figs. 39 - 46 it is marked by arrows.

3rd level of complexity (flow process, equilibrium system):

The process of the first order takes the bonding levels downwards, the flow of energy the same bonding levels upwards. The processes of the second order on the other hand proceed horizontally. They supply these at the bonding levels at each stage of the processes of the first order (see fig. 41). In so doing, the direction → or ← is changed:

2-3-4-1 →
1-4-3-2 ←

In accordance with the contrary course of the flow of energy from bottom to top, the lower part of the number table is folded behind the upper part. In this way the system is formed, receives its stability and forms the structure for the predominant process of the energy flows of the first order.

4th level of complexity (conversion process, non-equilibrium system):

In the process of the first order, the basic processes are a)

2	3	4	1
1	4	3	2
4	1	2	3
3	2	1	4
3	2	1	4
4	1	2	3
1	4	3	2
2	3	4	1

b)

2	3	4	1	1st bond ing level
1	4	3	2	2nd bond ing level
4	1	2	3	3rd bond ing level
3	2	1	4	4th bond ing level

Fig. 41:
Scheme of the flow process.
a) in the interlacement stage,
b) in the folding stage.
(Source: see "Notes on the figures").

doubly opposed, i.e. the following sequence results (see fig. 42):

$$\overrightarrow{1\text{-}2\text{-}3\text{-}4}\text{-}4\text{-}3\text{-}2\text{-}1 \;/\; 1\text{-}2\text{-}3\text{-}4\text{-}\overleftarrow{4\text{-}3\text{-}2\text{-}1}$$

This corresponds to the process sequence perception ... stabilisation in the induction and reaction process. The fact that, in reality, only 13 and not 16 stages are defined (see section 2.4.3.2) is not taken into account here.

a) ←

Sta	Kin	Dyn	Org	Org	Reg	Det	Per
1	2	3	4	4	3	2	1
4	3	2	1	1	2	3	4
3	4	1	2	2	1	4	3
2	1	4	3	3	4	1	2
2	1	4	3	3	4	1	2
3	4	1	2	2	1	4	3
4	3	2	1	1	2	3	4
1	2	3	4	4	3	2	1

b) ←

Sta	Kin	Dyn	Org	Org	Reg	Det	Per
1	2	3	4	4	3	2	1
4	3	2	1	1	2	3	4
3	4	1	2	2	1	4	3
2	1	4	3	3	4	1	2

Fig. 42:
Scheme of the conversion process.
in the interlacement stage,
in the folding stage.
Abbreviations: Per = perception, Det = determination,
Reg = regulation, Org = organisation, Dyn = dynamisation,
Sta = stabilisation.
(Source: see "Notes on the figures").

The processes of the second order are the flows supplying the bonding levels (of the third level of complexity) between the superior and inferior environment, whereby, in each case, the flows of information are contrary to those of energy.

5^{th} level of complexity (hierarchical process, hierarchical system):

The processes of the first order take place vertically (see fig. 43). This is the induction-process sequence of the non-equilibrium systems (of the 4^{th} level of complexity) brought into the vertical position. This is the flow of information (order-obedience relationship). The reaction process is carried out within each hierarchical level by the non-equilibrium systems present there.

The processes of the second order supply the processes of the first order horizontally at each hierarchical level, whereby the directions alternate in each case:

Processes of the 2^{nd} order

```
   ←     ←
1-4-3-2-2-3-4-1    ↓Process
   →     ←         ↓1st order
2-3-4-1-1-4-3-2    ↓
.
.
```

a)

1 4 3 2	2 3 4 1
2 3 4 1	1 4 3 2
3 2 1 4	4 1 2 3
4 1 2 3	3 2 1 4
4 1 2 3	3 2 1 4
3 2 1 4	4 1 2 3
2 3 4 1	1 4 3 2
1 4 3 2	2 3 4 1
1 4 3 2	2 3 4 1
2 3 4 1	1 4 3 2
3 2 1 4	4 1 2 3
4 1 2 3	3 2 1 4
4 1 2 3	3 2 1 4
3 2 1 4	4 1 2 3
2 3 4 1	1 4 3 2
1 4 3 2	2 3 4 1

b)

1 4 3 2 2 3 4 1	Per
2 3 4 1 1 4 3 2	Det
3 2 1 4 4 1 2 3	Reg
4 1 2 3 3 2 1 4	Org
4 1 2 3 3 2 1 4	Org
3 2 1 4 4 1 2 3	Dyn
2 3 4 1 1 4 3 2	Kin
1 4 3 2 2 3 4 1	Sta

Fig. 43:
Scheme of the hierarchical process.
a) in the interlacement stage,
b) in the folding stage.
Abbreviations: Per = perception, Det = determination,
Reg = regulation, Org = organisation, Dyn = dynamisation,
Sta = stabilisation.
(Source: see "Notes on the figures").

6th level of complexity (universal process and universal system):

As a result of the folding stage, we find 16 stages horizontally (1st order) and 16 stages vertically (2nd order). This results in 16 (through overlapping in reality only 13) spheres in the macro and microcosmos, i.e.

$$\overrightarrow{1\text{-}2\text{-}3\text{-}4\text{-}4\text{-}3\text{-}2\text{-}1} \;/\; \overleftarrow{1\text{-}2\text{-}3\text{-}4\text{-}4\text{-}3\text{-}2\text{-}1}$$

a) Microcosmos ← Macrocosmos

1234 4321	1234 4321
4321 1234	4321 1234
3412 2143	3412 2143
2143 3412	2143 3412
2143 3412	2143 3412
3412 2143	3412 2143
4321 1234	4321 1234
1234 4321	1234 4321
1234 4321	1234 4321
4321 1234	4321 1234
3412 2143	3412 2143
2143 3412	2143 3412
2143 3412	2143 3412
3412 2143	3412 2143
4321 1234	4321 1234
1234 4321	1234 4321

b)

			Microcosmos				←				Macrocosmos				
1	2	3	4	4	3	2	1	1	2	3	4	4	3	2	1
4	3	2	1	1	2	3	4	4	3	2	1	1	2	3	4
3	4	1	2	2	1	4	3	3	4	1	2	2	1	4	3
2	1	4	3	3	4	1	2	2	1	4	3	3	4	1	2
2	1	4	3	3	4	1	2	2	1	4	3	3	4	1	2
3	4	1	2	2	1	4	3	3	4	1	2	2	1	4	3
4	3	2	1	1	2	3	4	4	3	2	1	1	2	3	4
1	2	3	4	4	3	2	1	1	2	3	4	4	3	2	1
Sta	Kin	Dyn	Org	Org	Reg	Det	Per	Sta	Kin	Dyn	Org	Org	Reg	Det	Per
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
				Ato	Ion	Mol		Bios	Che	Pla	Sol				

Fig. 44:

Scheme of the universal process.

a) in the interlacement stage,
b) in the folding stage.
Abbreviations: Per = perception, Det = determination, Reg = regulation, Org = organisation, Dyn = dynamisation, Sta = stabilisation. Ato = sphere of the atoms, Ion = sphere of the ions, Mol = molecular sphere, Bios = biosphere, Che = chemosphere, Pla = sphere of the planets, Sol = sphere of the solar systems.
(Source: see "Notes on the figures").

These horizontal processes of the first order supply the vertically arranged processes of the second order (i.e. those taking place within the spheres), and the direction up or down alternates for each sphere as in the systems of the previous level of complexity (see fig. 44).

Taken as a whole, the result is a generally valid description of the process sequences in the systems of the levels of complexity. To put it more plainly, the folded process structures (which reflect the status of the last, the fourth operation of the emergence process) are the systems which serve the predominating process (of the first order) as a framework. In the short discussion of the table, only the processes of the first and second order are given, although these subordinate processes (of the third order etc.) are also contained in the tables. This becomes apparent when the processes of all system types are brought together in 2 figures (see fig. 45) representing the levels of complexity in which the processes of the first order are aligned horizontally or vertically.

a)

1	4	3	2	2	3	4	1	
2	3	4	1	1	4	3	2	1
3	2	1	4	4	1	2	3	
4	1	2	3	3	2	1	4	3
4	1	2	3	3	2	1	4	
3	2	1	4	4	1	2	3	
2	3	4	1	1	4	3	2	
1	4	3	2	2	3	4	1	5

b)

6								4				2			
1	2	3	4	4	3	2	1	1	2	3	4	4	3	2	1
4	3	2	1	1	2	3	4	4	3	2	1	1	2	3	4
3	4	1	2	2	1	4	3	3	4	1	2	2	1	4	3
2	1	4	3	3	4	1	2	2	1	4	3	3	4	1	2
2	1	4	3	3	4	1	2	2	1	4	3	3	4	1	2
3	4	1	2	2	1	4	3	3	4	1	2	2	1	4	3
4	3	2	1	1	2	3	4	4	3	2	1	1	2	3	4
1	2	3	4	4	3	2	1	1	2	3	4	4	3	2	1

Fig. 45:
The processes of the complexity levels summarised (folding stages):
a) The processes of the first level of complexity appear in the process of the third level of complexity. The processes of the third level of complexity appear in the process of the fifth level of complexity.
b) The processes of the second level of complexity appear in the process of the fourth level of complexity. The processes of the fourth level of complexity appear in the process of the sixth level of complexity.
(Source: see "Notes on the figures").

3.2.4. The process trains

We now have a basis which allows us to come closer to understanding the "mechanism" behind the processes and emergence. Our thesis is as follows:

Increasing complexity is associated with an increasing involvement of the environment in its various forms ("environments"). We are dealing with two different process trains which affect one-another mutually. We have already described these with regard to the construction of the conversion processes and the non-equilibrium system (see section 2.4.3.1, 2.4.3.2). Here, they are placed within a larger context (see fig. 47):

- First process train: The impulses originate from the environment. Differentiation takes place within the system.
- Second process train: The differentiation is taken into the environment by the first process train.

To each process train are assigned 4 process or system types and two of these types belong to both trains.

The structuring or differentiation, i.e. the formation of the systems at the levels of complexity, originates from the first process train. At the 1st and 2nd levels of complexity, it alone is active to this end (even if the impulse for the internal flows of energy comes from the environment). At the 3rd and 4th levels of complexity, the second process train becomes active in the system-formation process. Both trains now permeate each other mutually. Common (non-linear) types of process and system come into being. At the 5th and 6th levels of complexity, the second process train takes over the task of shaping the system and previously shaped systems are involved as sub-systems and elements.

The emergence processes between the levels (see section 3.2.2) alternate their rotation direction (clockwise / anticlockwise; see fig. 46).

Formally, we could again describe the process trains using a system of co-ordinates, which we will call the "train co-ordinate system". Unlike the emergence processes, both process trains develop in a mathematically negative direction of circulation, i.e. in a clockwise direction (see fig. 47). For the process sequences in both train co-ordinate systems, the sequence of the basic process applies: 1. input, 2. acceptance, 3. redirection, 4. output.

The circulation of the processes in the co-ordinate systems of the individual levels of complexity on the other hand alternates, as already shown (see section 3.2.1). The sequences of the processes of emergence connecting the levels of complexity also alternate in the same way. Let us move up through the levels of complexity shown in our diagram level by level:

1st level of complexity: The solid is represented only in the first process train. In its co-ordinate system, it occupies

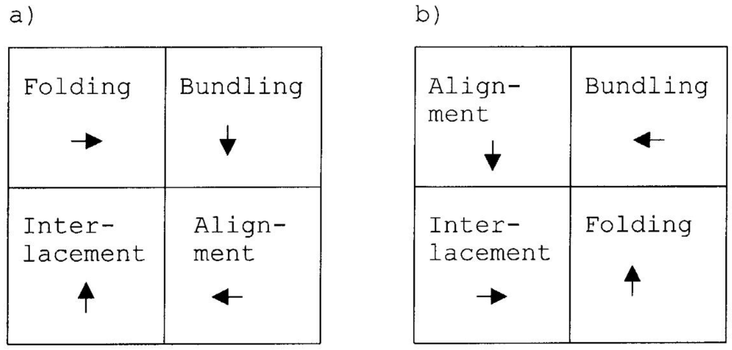


Fig. 46:
Basic direction of the processes of emergence between the complexity levels with the stages Bundling - Alignment - Interlacement - Folding.
a) right-hand direction of rotation, i.e. clockwise
b) left-hand direction of rotation, i.e. anti clockwise

the quadrant f(x). The energy is transmitted. The movement of the solid is determined from outside (the environment) only. The internal structure remains unaltered.

2nd level of complexity: the equilibrium system too is represented only in the first process train. In its co-ordinate system, it occupies the quadrant -f(x). The process of energy transfer is organised into a sequence in time. The first-order process (movement and action project) differentiates the course of time. The second-order process differentiate the transmission of energy internally. From the preceding environment, the system as a whole receives the stimulus. The elements adapt to the energetic environment and therefore remain in equilibrium.

3rd level of complexity: The flow-equilibrium system is represented in both process trains.
a) It occupies the quadrant -f(-x) in the co-ordinate system of the first process train. The sequence is therefore contrary to the solid. Here, it is not the transfer of energy which predominates, but the demand for energy, the flow of information. It shapes the internal hierarchy (bonding levels). Thus: the first-order process (flow process, demand for energy) differentiates the internal hierarchy in this first process train. The processes of the second order differentiate time, while those of the third order transfer the demand for energy to the inferior environment.
b) In the co-ordinate system of the second process train, the system occupies the quadrant f(x). From here, the demanded energy is input into the system as a flow of energy, i.e. the system includes the energetic environment (from the second process train). In this way, the system receives a new material basis.

1st process train				Transition	2nd process train			
					SSSS HHH TT E	→ f(-x)	US	Spatial environment
					HHH TT E	↑ -f(-x)	HS	Hierarchical environment
Spatial environment	NES	→ f(-x)	**SSSS** HHH TT E	E **TT** HHH SSSS	**TT** E	← -f(x)	NES	Temporal environment
Hierarchical environment	FES	↑ -f(-x)	**HHH** TT E		**E**	↓ f(x)	FES	Energetic environment
Temporal environment	ES	← -f(x)	**TT** E					
Energetic environment	SOL	↓ f(x)	**E**					

Fig. 47: L*evels of complexity in their "mechanical" context.*
In both process trains, the stages lead to greater complexity from the bottom upwards. The first process train (in which the ladder of increasing complexity begins) leads from solidum to non-equilibrium system, the second process train (which shapes the environment) from flow-equilibrium system to universal system. The environment is involved increasingly in the complex system structure. First the energetic, then the temporal, the hierarchical and finally the spatial environment are involved in the system control. At the complexity levels of the flow-equilibrium and non-equilibrium systems, the processes of both process trains act together. The non-equilibrium system is taken into the second process train as an element and incorporated temporally. The internal process hierarchy is turned around (see column Transition). The complexity levels of both process trains each pass through the co-ordinate system. Their position in a quadrant appears as a separate column in the diagram.
Symbols:
E = energy, T = time, H = hierarchy, S = space. The number of these symbols appearing together in each case represents the position in the sequence of creation. The symbol combinations appearing in bold print indicate the dominant process.
SOL = solidum, ES = equilibrium system, FES = flow equilibrium system, NES = non-equilibrium system, HS = hierarchical system, US = universal system.
f(x) etc. = quadrant in the co-ordinate system of the first or second process train. The arrows indicate the sequence of the process in the co-ordinate system.

The transition from the 3rd to the 4th level of complexity is of special interest. When more energy is demanded from the superior environment than the system can supply, the system

comes under pressure and is forced to make better use of the energy. Two steps can be distinguished here:
a) within the context of the first process train, the spatial concentration on the most favourable points in the regions of the inferior environment, and
b) within the second process train, the temporal differentiation of the better utilisation of the flow of energy in each case. This is carried out at the 4th level of complexity.

4th level of complexity: In the same way, the non-equilibrium system is also present in both process trains:
a) In the co-ordinate system of the first process train, it occupies the quadrant f(-x). In the competitive struggle of the non-equilibrium systems (e.g. the organisates) within the superior flow-equilibrium systems (e.g. in the market) for the best supply of energy, those with better access to the sources of energy have an advantage. Here the level of attractiveness is greatest. A slight advantage at the beginning is sufficient to influence the development. From here, the system shapes its spatial construction and structurally creates its sphere of influence in the spatial environment. In this process train, the 1st ranking process is dedicated to ordering space, the 2nd ranking process to ordering the hierarchy, the 3rd ranking process to ordering time and the 4th ranking process to ordering energy. In this way, the process of the first process train finds its completion.
b) In the second process train, two operations should be distinguished:
First: In the co-ordinate system of the second process train, the system occupies the quadrant -f(x). The temporal environment adds to the system's own induction process the process of reaction. Thus the temporal sequence is ordered and secured materially.
Second: Turning around the internal hierarchy of the processes so that the 1st ranking process is dedicated to ordering the flow of energy (main process), the 2nd ranking process to ordering the course of time (task process), the 3rd ranking process to ordering the hierarchy (control process) and the 4th ranking process to ordering the internal space (elementary process)(see section 2.4.3.2). This is apparently necessary, because the non-equilibrium system as a whole is changed over from the first to the second process train in order to serve as a sub-system or element at the 5th level of complexity (hierarchical system).

5th level of complexity: The hierarchic system is represented only in the second process train. In the co-ordinate system of this process train, it occupies the quadrant -f(-x). The hierarchy is shaped. The process of the first order is therefore devoted to the hierarchy (control), the processes of the second order to time and the process of the third order to energy. The non-equilibrium systems of the subordinate levels of complexity are inserted as modules in the hierarchical levels or are eliminated (selection). In this way, the hierarchical system is preserved in its structure and re-created again and again.

6^{th} level of complexity: The universal system is also represented in the second process train only. In the train co-ordinate system, it occupies quadrant f(-x). Space and matter are shaped. Thus, the process of the first order is dedicated to space, the processes of the second order to hierarchy, those of the third order to time and those of the fourth order to energy. The hierarchical systems and non-equilibrium systems etc. are joined spatially in spheres which shape the macro and microcosmos. The systems create themselves not only structurally, but also materially and spatially (autopoiesis).

The increase in complexity from level to level is therefore associated with the construction of larger aggregates, each of which contains many units (processes and systems) of the lower level of complexity. This also means that the control is more comprehensive. Moreover, the systems achieve more independence. Whereas the (solids and) systems of the three lowest levels of complexity are regulated substantially by the environments, the systems of the three higher levels are able to maintain themselves in the flows of information and energy by organising themselves and acquiring energy from the environment. It is therefore possible for them to control their energy resources and to counteract the destruction of order as would be expected in accordance with the Second Principle of Thermodynamics (entropy).

In this process of the highest grade leading from one level of complexity to the next, the dimensions are revealed, on which, from a systemic point of view, our reality is founded. On the 6-step ladder of complexity, the process of energy transmission as a whole appears at the first level. The systemic dimensions are not yet differentiated. At the second level, time and space are taken out. It is only at the third level of complexity that the four systemic dimensions become separately recognisable. The fundamental alignment of the dimensions (vertical, horizontal) changes as already outlined in sections 3.2.1 and 3.2.3. Taken as a whole, the result is:
- undifferentiated transmission of energy: simple movements and solida (vertically aligned);
- temporal-spatial dimension in association: movement projects and equilibrium systems (horizontally aligned);
- energetic dimension: flow processes and flow-equilibrium systems (vertically aligned);
- temporal dimension: conversion processes and non-equilibrium systems (horizontally aligned);

- hierarchical dimension: hierarchical processes and hierarchical systems (vertically aligned);
- spatial dimension: universal process (autopoietic processes) and universal system (horizontally aligned);

Apparently, a clear division of the 4 system dimensions only becomes possible through the co-operation of the two process trains (see above).

The structuring itself, an increase in the information content, is due firstly to the first process train. It is effective throughout four levels of complexity and leads to structural self-organisation, to the process of conversion and non-equilibrium system. The four dimensions (energy, time, hierarchy and space) are separated, but only on the one side, acting from the interior on each environment. Conversely, matter is shaped by the environment in the second process train. Here too, four levels of complexity should be distinguished in which the four dimensions (energy, time, hierarchy and space/matter) are separated and defined materially. This second train leads to material self-creation, to autopoiesis. In this way, the processes and systems, located in the two process trains have dimensioned themselves, each acting on its own.

3.3. Review and prospects

The process theory outlined above attempts to render complex reality at the level of the flow of information and energy more understandable. At this level, the difference between mankind and nature loses its validity. In the discussion, the broadly inductive results are described inasmuch as they can be described by rules and wherever possible, defined mathematically. In order to decide whether the construction is plausible, the reader should regard all the results and hypotheses in relation to one another. I hope that no blatent contradictions become apparent.

This theory is however not intended to call into question the principles developed by earlier researchers into complexity. Each method of explaining the processes and systems has, without doubt, its own validity. These approaches do not become obsolete with the appearance of a new theory. Care only has to be exercised in deciding to which phenomena they can be applied and to which they cannot.

Perhaps it is safe to say that the process theory described here is based on a few simple statements:

1) Our reality appears as a finely veined fabric of process sequences possessing a complex structure and several dimensions. The process sequences make up the flows of information and energy. The structuring processes must be seen within their environment. Processes or systems and the environment inter-react with one another in the two process trains. The processes of differentiation which lead to the hierarchy of the levels of complexity are due to their co-operation. The structuring itself, the increase in the information content is initially attributable to the first process train. By contrast, matter and energy is shaped by the environment in the second process train.
2) Processes and systems are the two sides of the same phenomenon. The process of emergence creates process and system equally. For example, the solidum would only be substance, if no external impulse caused it to become a moving or changing unit. Another example: the non-equilibrium system would disintegrate if the conversion process did not supply it with information and energy, as conversely, the process requires a framework for stabilisation.
3) The pressure towards successiveness in the course of the processes leads to a division, i.e. a differentiation. The "basic process" forms the starting point. It has four stages (input, acceptance, redirection and output), and these individual stages may also be sub-divided in their turn. In this way, the flows of information and energy are divided up, quantised. Each division takes place in the flow of

information and/or energy, i.e. the divided parts remain connected with one another in a network.
4) Each division takes place along the four system dimensions (energy, time, hierarchy and space). All systems and processes align themselves along these dimensions. They dictate the direction, they are vectors. In this way, the processes and systems receive their four-dimensional shape and four-dimensional volume.

However, it did not prove possible to resolve the question as to why the flows of information and energy are structured in the first place, i.e. why systems are formed. According to the Second Principle of Thermodynamics, the reverse should be the case, i.e. it should be the entropy which increases. In order to clarify this point, a broader approach has to be adopted. The process theory was developed from the area of the mesocosmos, so it was only possible to formulate the inductive basis for this theory in the field with which I am most familiar.

But here too, there are still many questions to be solved, of which I would to mention just two.

1) In the biosphere, the most highly developed sphere of the 6^{th} level of complexity, the great variety of forms is striking. Living creatures are the "equifinal" (BERTALANFFY 1950, S. 25) result of the autopoietic processes (see section 2.6) and possess a fixed structure which applies for the duration of their existence. However, if we adhere to the model which I have proposed, primarily geometrically simple forms with a central-peripheral structure should come into being. Perhaps the key to this variety of forms lies in DNA. The autopoietic systems of the biosphere, i.e. living creatures, have only a limited lifespan (see section 2.6.3.1), a fact which makes the food cycle possible in the first place. To occupy the ecological niches in the best way possible to ensure an efficient flow of energy, not the individuals, but the species have to maintain themselves or the area systems be able to develop.

The model for the process theory presented here is based on the thesis that the process stages are always worked through in a certain sequence (see sections 2.4.3.2, 3.2.3 etc.). This would also mean that the four dimensions in development should also be considered in a certain order (i.e. first the flow of energy, then the sequence in time, then the hierarchic arrangement above and below one another, and finally the spatial arrangement around one another). Could it be possible that in the case of DNA (which itself does not represent a process sequence and does not have to adhere to this principle) this order does not apply, i.e. that in the development of living creatures the four dimensions can also be considered in a different order?

2) As an anthropogeographer, yet another problem is particularly close to my heart, i.e. the continuing differentiation of mankind as a society. With cultural evolution, mankind created a hierarchical order in which the basic tasks are institutionalised at various hierarchical levels (see section 2.5.3). Let us call this the differentiation process of the first degree. In addition however, a countless number of subsystems have also formed to deal with these tasks in detail. (Typologically, they are structured in the same way as the 6 archetypes.) Some of these types of subsystem exist in all orders of magnitude. Thus, there are organisates which are run by one person as small businesses, but also organisates which as multi-national companies are present all over the globe. How does this differentiation process of the second grade take place? How is it controlled? How does this highly complex creation of mankind as a society "work", how is the network of information and energy flows linked together? What are the mechanisms continually pursue the development of order in the whole, and where does it lead? The following are a few suggestions as to how we may proceed in accordance with the process theory:

In contrast to the living creatures (as autopoietic systems) the social populations of mankind as a society (as non-equilibrium systems) are not limited per se in their size or in their life span. However, like the living creatures, they are structurally "equifinally" programmed, i.e. in principle, they always aspire to the same internal structure. And as with death in the living creatures, the order of their process sequences is also interrupted with the elimination of the social populations. Man as a planner substantially assumes the role of DNA when a new population is created. But man of course is much more variable in how he shapes a system, he can adapt his actions to the existing circumstances.

That means, within the hierarchical levels of mankind as a society, the populations can develope freely in all 4 system dimensions, i.e. re-orient themselves materially, produce more slowly or more quickly, divide themselves hierarchically or enlarge or diminish themselves. Only the basic rules, as they are laid down in the program of the non-equilibrium systems (see section 2.4) have to be observed, i.e. the process sequences have to be completed in full.

However, there are differences depending on the task or its material form defined by the basic institutions at the various hierarchic levels. A more extensive differentiation (for example within the states) will normally be apparent in a more extensive administrative division, perhaps leading to more efficient control.

City-umland populations on the other hand may form smaller hierarchically inferior city-umland systems which on their part are surrounded by smaller systems. On the other hand, they may belong to the sphere of influence of hierarchically superior city-umland systems resulting in a multi-stage hierarchy of spaces (see section 2.5.3.4). Communities on the other hand, may form administrative sub-departments or commissions which improve the infrastructure of their territory in accordance with their allocated task.

The organisate is of special importance as an agent in the process of differentiation of mankind as a society. Because it is relatively easy to control, it is particularly suited for advancing the differentiation of society. Organisates compete with one another on the market. They are frequently (1) forced to specialise materially. In this way it is possible to achieve greater suitability of products, i.e. more efficient shaping of the flows of information and energy. This also leads to increasing specialisation of the markets. Then the tendency exists (2) to increase the speed of production, which is facilitated by the division of labour. This makes increasingly elaborate control necessary (3), i.e. development of the internal hierarchy. This is encouraged (4) by a strong drive to expand on the part of the organisates. In their attempt to achieve a maximum of effect for a minimum of effort, economic organisates may take over or merge with other organisates. In this way they can expand, perhaps forming worldwide concerns. Globalisation is primarily but not exclusively attributable to the organisates. This development could not take place without the fundamental principle of our western culture, i.e. without the capitalistic economic system (WEBER 1920).

And where does this lead? Will biotic evolution be supplanted in the superior flow of information and energy by the (probably) more efficient process of cultural evolution? The decline in the variety of biotic species is becoming more and more rapid. Will these gaps be filled by mankind? If cultural evolution had this task, it would also mean that the energies (the activities of the acting, the shaping of the materials etc.) would be integrated in a new cycle. This may be true on a general sense. But there are also problems. Material which is not renewable (e.g. many plastics, toxins, nuclear waste) are removed from the cycle of energy. There are no long-term solutions for dealing with this kind of material. But mankind, which operates the flows of energy and information does not act reasonably in this respect either. The wide gap between rich and poor indicates that the flows of energy are very uneven and that they have come to halt in many places. Many people play no part in the global economy. This leads to tensions and ruptures. These in turn lead to wars and the production of increasingly destructive weapons, which, in our sense, are dead assets. Planet earth is becoming an increasingly dangerous place for mankind. Insufficient attention is paid to the fact that western culture has not only produced capitalism, but has also - like the other cultures - set ethical standards. Only when these form the basis of human action can cultural evolution in the world as a whole be given sense and direction.

References

ABLER, Ronald, John S. ADAMS, and Peter GOULD (1971): Spatial Organisation, the Geographer`s View of the World. Englewood Cliffs, N.J. (Prentice Hall).

BARTELS, Dietrich (1968): Zur wissenschaftlichen Grundlegung einer Geographie des Menschen. = Geographische Beihefte (= Erdkundliches Wissen 19). Wiesbaden.

BERTALANFFY, Ludwig von (1950): The Theory of open Systems in Physics and Biology. In: Science, Vol.111, pp. 23-29.

BOBEK, Hans (1928): Innsbruck. Eine Gebirgsstadt, ihr Lebensraum und ihre Erscheinung. = Forschungen zur Deutschen Landeskunde 25,3. Stuttgart.

BOBEK, Hans (1948): Stellung und Bedeutung der Sozialgeographie. In: Erdkunde II, pp. 118-125.

BRAUDEL, Fernand (1958/92): Geschichte der Sozialwissenschaften. Die lange Dauer. In: Braudel, F.: Schriften zur Geschichte, Bd. 1. (Aus dem Franz.: Histoire et sciences sociales. La longue durée). Stuttgart (Klett-Cotta). pp. 49-87.

BUNGE, Mario (1959/87): Kausalität. Geschichte und Probleme. (Aus dem Amer.: Causality: The Place of the Causal Principle in Modern Science, 1st ed. 1959). Tübingen (Mohr).

BURGESS, E.W. (1925/67): The Growth of the City. In: PARK, R.E., E.W.Burgess and R.D.MCKENZIE (Eds.): The City. Chicago (1. ed. 1925). pp. 47 - 62.

CHILDE, V.Gordon (1936/51): Man makes himself. (1. ed. 1936). New York (Signet, Mentor Books).

CHRISTALLER, Walter (1933): Die zentralen Orte in Süddeutschland. Jena (Fischer).

CZAJKA, Willi (1964): Beschreibende und genetische Typologie in der ostmitteleuropäischen Siedlungsformenforschung. In: Schriften des Geographischen Instituts der Universität Kiel, Vol. XXXXIII, pp. 37-62.

ELLENBERG, Hans (1973): Ziele und Stand der Ökosystemforschung. In: ELLENBERG, Hans (editor): Ökosystemforschung. Berlin/Heidelberg/New York. pp.1-31.

EPSTEIN, Joshua M. and Robert AXTELL (1996): Growing Artificial Societies. Social Science from the Bottom up.

Washington (Brookings Institition Press)/Cambridge, Mass.(MIT Press).

FISZ, Marek (1976): Wahrscheinlichkeitsrechnung und mathematische Statistik. Berlin (VEB Deutscher Verlag der Wissenschaften).

FORRESTER, Jay W. (1968/72): Grundzüge einer Systemtheorie. (Aus dem Amerik.: Principles of Systems, 1st ed. 1968. Wiesbaden (Gabler).

FORRESTER, Jay W. (1969): Urban Dynamics. Cambridge, Mass. (MIT Press).

FRIEDRICH, H. and BRAUER, U. (1985): Arbeitslosigkeit. Dimensionen, Ursachen und Bewältigungsstrategien. Opladen (Westdeutscher Verlag).

GADAMER, Hans-Georg (1960/90): Wahrheit und Methode. Grundzüge einer philosophischen Hermeneutik. 2 Vols. (1st ed. 1960). Tübingen (Mohr).

GARRISON, W.L. (1959-60): Spatial Structure of the Economy. In: Annals of the Association of American Geographers, Vol. 49, pp. 232-239, 471-482; Vol. 50, pp. 357-373.

GIDDENS, Anthony (1984/88): Die Konstitution der Gesellschaft. (Aus dem Engl.: The Constitution of Society. Outline of the Theory of Structuration. 1st ed. 1984). Frankfurt a.M. (Campus).

HÄGERSTRAND, Torsten (1952): The Propagation of Innovation Waves. = Lund Studies in Geography, Ser. B., No.4. Lund.

HÄGERSTRAND, Torsten (1953/67): Innovation Diffusion as a Spatial Process. (Translation and postscript by Allan Pred). Chicago, London (Univ. of Chicago Press).

HAHN, Helmut (1957): Sozialgruppen als Forschungsgegenstand der Geographie. Gedanken zur Systematik der Anthropogeographie. In: Erdkunde XI, pp. 35 - 41.

HAKEN, Hermann (1977/83): Synergetik. Eine Einführung (Aus dem Amerik.: Synergetics. An Introduction). 2. Aufl. Berlin/New York (Springer)

HARD, Gerhard (1970): Die "Landschaft" der Sprache und die "Landschaft" der Geographen. = Coll. Geographicum 11. Bonn.

HARTKE, Wolfgang (1953): Die soziale Differenzierung der Agrarlandschaft im Rhein-Main-Gebiet. In: Erdkunde VII, pp. 11-27.

HETTNER, Alfred (1927): Die Geographie. Ihre Geschichte, ihr Wesen und ihre Methoden. Breslau.

KESSEL, John L. (1975): The Pueblo de los Pecos. A documentary history 1540 - 1838. Manuscript (by order of the National Park Service, USA). Albuquerque. [Now published]

KLUCZKA, G. (1970): Zentrale Orte und zentralörtliche Bereiche mittlerer und höherer Stufe in der Bundesrepublik Deutschland. = Forschungen zur deutschen Landeskunde 194. Bad Godesberg.

KLUG, Heinz und Robert LANG (1983): Einführung in die Geosystemlehre. Darmstadt (Wissenschaftliche Buchgesellschaft).

KROHN, Wolfgang und Günter KÜPPERS (Hrsg.)(1992): Emergenz: Die Entstehung von Ordnung, Organisation und Bedeutung. 2nd ed. Frankfurt a.M. (Suhrkamp).

LANGTON, Christopher G. (1989): Artificl Life. = Santa Fe Institute Studies in the Sciences of Complexity, Vol. 6. Redwood City, Cal. (Addison-Wesley).

LENK, Hans (Hrsg.) (1977-1982): Handlungstheorie interdisziplinär. 4 Vols. München.

LESER, Hartmut (1976): Landschaftsökologie. Stuttgart (Ulmer, UTB).

LILIENTHAL, Karl (1931): Jürgen Christian Findorffs Erbe. Ein Beitrag zur Darstellung der kolonisatorischen Entwicklung der Moore im alten Herzogtum Bremen. Osterholz-Scharmbeck (Saade).

LOTKA, A.J. (1925/56): Elements of Mathematical Biology. Reprint. New York (Dover).

LUHMANN, Niklas (1984): Soziale Systeme. Grundriß einer allgemeinen Theorie. Frankfurt a.M. (Suhrkamp).

LUHMANN, Niklas (1998): Die Gesellschaft der Gesellschaft. 2 Vols. Frankfurt a.M. (Suhrkamp).

MANDELBROT, Benoît B. (1977/1987): Die fraktale Geometrie der Natur. (Aus dem Amerik.: The Fractal Geometry of Nature, 1st ed. 1977). Basel/Boston (Birkhäuser).

MATURANA, Humberto R. and Francisco J. VARELA (1984/89): Der Baum der Erkenntnis. Die biologischen Wurzeln des menschlichen Erkennens. (Aus dem Span.: El árbol del concocimiento, 1st ed. 1984) München (Scherz).

MATURANA, Humberto R. (1998): Biologie der Realität. Frankfurt a.M. (Suhrkamp).

MENSCH, Gerhard (1975) Das technologische Patt. Innovationen überwinden die Depression. Stuttgart (Umschau).

MÜLLER, Paul (1981): Arealsysteme und Biogeographie. Stuttgart.

NEWTON, Isaac (1681/1725/1963): Mathematische Prinzipien der Naturlehre. (Aus dem Lat. Philosophiae naturlalis principia mathematica, 1st ed. 1681). Editor: J.Ph. Wolfers. Unveränderter Nachdruck von 1872. Darmstadt (Wissenschaftliche Buchgesellschaft).

NOSTRAND, Richard (1995): The spread of spanish settlement in greater New Mexico: An isochronic map, 1610-1890. In: Journal of the West, Vol. XXXIV, No 3, July 1995, pp. 82-87.

PITTENDRIGH, C.S. (1958): Adaptation, natural selection, and behavior. In: ROE, A., G.G. SIMPSON (eds.): Behavior and Evolution. London/New Haven (Yale Univ. Press)., pp. 390-416.

POHL, Jürgen (1998): Von der agrarischen Lebensform zur postmodernen Patchwork-Identität: Die Funktion der Sozialgeographie im Wandel der Zeit. In: Günter Heinritz & Ilse Helbrecht (editors): Sozialgeographie und Soziologie. Dialog der Disziplinen. = Müncher Geographische Hefte, 78. Passau (L.I.S.Verlag). pp. 57-73.

POHL, Robert Wichard (1947): Einführung in die Mechanik, Akustik und Wärmelehre. (10. und 11. ed.). Berlin/Göttingen (Springer).

POPPER, Karl (1934/89): Logik der Forschung. 9. ed. Tübingen (Mohr).

POSER, Hans (Hrsg.)(1982): Philosophische Probleme der Handlungstheorie. = Reihe: Praktische Philosophie. Freiburg/München (Karl Alber).

PRIGOGINE, Ilya (1979): Vom Sein zum Werden. Zeit und Komplexität in den Naturwissenschaften. (Aus dem Engl.: From Being to Becoming, 1979). München/Zürich (Piper).

RIEDL, R. (1979/88): Biologie der Erkenntnis. Die stammesgeschichtlichen Grundlagen der Vernunft. München.

ROGERS, E.M. (1962/83): Diffusion of Innovations. 3rd ed. New York, London.

SAUER, Carl Ortwin (1952): Agricultural Origins and Dispersals. New York (Americ.Geogr.Society).

SCHLÜTER, Otto (1906): Die Ziele der Geographie des Menschen. München/Berlin.

SCHMITHÜSEN, Josef (1976): Allgemeine Geosynergetik. = Lehrbuch der Allgemeinen Geographie XII. Berlin/New York (de Gruyter).

SCHULTZE, Arnold (1962): Die Sielhafenorte und das Problem des regionalen Typus im Bauplan der Kulturlandschaft. = Göttinger Geographische Abhandlungen 27, Göttingen.

SCHUMPETER, Joseph Alois (1939/61): Konjunkturzyklen. Eine theoretische, historische und statistische Analyse des kapitalistischen Prozesses. 2 Vols. (1st ed. 1939). Göttingen.

SCHWARZ, Reiner (1981): Informationstheoretische Methoden. = Geomod, 2. Paderborn (Schöningh).

SHANNON, Claude E. und Warren WEAVER (1949/76): Mathematische Grundlagen der Informationstheorie. (Aus dem Amerik.: The Mathematical Theory of Communication, 1st ed. 1949). München/Wien (Oldenbourg).

SOCHAVA, V.B. (1972): Geographie und Ökologie. In: Petermanns Geographische Mitteilungen, 116, pp. 89-98.

THÜNEN, Johan Heinrich v. (1926/1921): Der isolirte Staat in Beziehung auf Landwirtschaft und Nationalökonomie. 2nd ed. Jena.

VOLLMER, Gerhard (1985-86): Was können wir wissen? 2 vols. Stuttgart (Hirzel).

WEBER, Max (1920): Die protestantische Ethik und der Geist des Kapitalismus. In: WEBER, M.: Gesammelte Aufsätze zur Religionssoziologie. Tübingen. Vol. 1, pp. 18-56.

WERLEN, Benno (1988): Gesellschaft, Handlung und Raum. Grundlagen handlungstheoretischer Sozialgeographie. 2nd ed. Stuttgart.

WERLEN, Benno (1995-97): Sozialgeographie alltäglicher Regionalisierungen. = Erdkundliches Wissen, 116 and 119. Stuttgart (Steiner).

WIENER, Norbert (1948/68): Kybernetik. Regelung und Nachrichtenübertragung in Lebewesen und Maschinen. (Aus dem Amerik.: Cybernetics or Control and Communication in the animal and the machine, 1st ed. 1948). Reinbek bei Hamburg (Rowohlt).

WIESER, Wolfgang (1998): Die Erfindung der Individualität, oder die zwei Gesichter der Evolution. Heidelberg/Berlin (Spektrum).

Publications of the author:

(1962 a): Zyklonale Tendenzen bei Bevölkerungs- und Verkehrsbewegungen in städtischen Bereichen, untersucht am Beispiel der Städte Göttingen, München und Osnabrück. In: Neues Archiv für Niedersachsen 10(15), pp. 277-294.

(1962 b): Zu- und Abwanderung im Bereich einer deutschen Mittelstadt, dargestellt am Beispiel der Stadt Göttingen. In: Neues Archiv für Niedersachsen 11 (16), pp. 14-31.

(1969): Formungstendenzen und Formungsphasen in der Entwicklung der ländlichen Kulturlandschaft seit dem hohen Mittelalter, besonders in Nordwestdeutschland. In: Erdkunde XXIII, pp. 102-116.

(1974): Räumliche Wirkungsprinzipien als Regulative strukturverändernder und landschaftsgestaltender Prozesse. In: Geographische Zeitschrift 62, pp. 12-28.

(1975): Die Kolonisierung New Mexicos durch die Spanier. Ein Beitrag zum Problem der Entstehung von anthropogenen Räumen. = Arbeiten aus dem Geographischen Institut der Universität des Saarlandes 21. Saarbrücken.

(1981): Society in Space and Time. = Arbeiten aus dem Geographischen Institut der Universität des Saarlandes 31. Saarbrücken.

(1987): Prozeßsequenzen und Musterbildung. Ein anthropogeographsicher Forschungsansatz, dargestellt am Beispiel des Stadt-Umland-Systems. In: Erdkunde 41, pp. 106-117.

(1990): Die Entwicklung des Raumverständnisses in der Anthropogeographie in den letzten hundert Jahren. = Karlsruher Manuskripte zur Mathematischen und Theoretischen Wirtschafts- und Sozialgeographie. Vol. 93. Karlsruhe.

(1993): Sozialgeographie. = Lehrbuch der Allgemeinen Geographie, Vol. 13. Berlin/New York (de Gruyter).

(1997): Die komplexe Natur der Gesellschaft. Systeme, Prozesse, Hierarchien. Frankfurt a.M., Berlin etc. (Peter Lang).

(1999): Komplexität und Emergenz in Gesellschaft und Natur. Frankfurt a.M., Berlin etc. (Peter Lang).

(2001): Six Levels of Complexity; A Typology of Processes and Systems. In: Journal of Artificial Societies and Social Simulation, Vol. 4, No.1 <http://www.soc.surrey.ac.uk/JASSS/4/1/4.html>

Notes on the figures:

Fig. 3:
Source: 1974 (fig. 3, p. 16).
Example of a) immigration to Göttingen from the Bundesrepublik Deutschland. Source: 1962 b.
Example of b) immigration of refugees in the years after World War II. Source: 1974, p. 14.
In practice, other facts are added and alter the picture, e.g. population density, economic structure, membership of political units, e.g. the state of Niedersachsen etc.

Fig. 4:
Source: 1981 (fig. 5, p. 52 and 273).
Field work in the years 1975/76 (see fig. 9).
Around the 1838 deserted Pueblo Pecos in New Mexico are the ruins of ca. 1200 small (mostly only one room) houses. Only identifiable rim-sherds of the P IV or modern period were taken into consideration, i.e. not Black-on-White or Culinary-Ware, because in the P III-period not Pecos (Quadrangle or North Pueblo) formed the central point, but the Forked-Lightning Pueblo approx. 300 m away. With the stone implements (resp. their fragments) a similar age differentiation could not be attempted. However, considering the small amount of fragments found near the pueblos, it seemed legitimate to neglect this aspect. Zones, each covering a distance of 200 m were set up around Pueblo Pecos and the fragments found in them counted.

Fig. 5:
Source: CARTER and ROWLEY, after MURPHY, Raymond E.: The central business district. A study in urban geography. London (Longman) 1971. P. 99.

Fig. 6:
Source: 1997 (fig. 4, p. 45).

Fig. 7:
Source: 1997 (fig. 1, p. 21). The model of the logistic equation is commonly used in population biology, but also in chaos research. Mathematical description, see section 2.3.3, no.9.

Fig. 8:
Source: 1997 (fig. 2, p. 24). This model too (Lotka-Volterra Equation) is also extensively used in population biology (predator-prey relationship) and in non-equilibrium-system physics. See LOTKA 1925/56; PRIGOGINE 1979 (p.108).
Mathematical description, see section 2.3 3, no.11.

Fig. 9:
Source: 1981 (fig. 10, p. 75).
Position and dating of field houses: field work.
It was possible to date the periods of field utilisation by means of the ceramics found in the houses, but only in the ruins which really represent relics of field houses. Many of these contained datable sherds. However, many of the houses were used not only as shelter during periods of field work, but were also used as temporary accomodation for hunters, as is indicated by the (undatable) stone tools frequently found in them. (See fig. 4).
The sherds were dated by me in the Laboratory of Anthropology, Santa Fe. For details, literature on the subject and the support which I received, see 1981.

Fig. 10:
Source: 1975 (fig. 3, p. 25/26. For a more detailed description of procedure, see pp. 94/95).
Dating of settlements, migration links: Archives in Santa Fe (Spanish Archive) and Mexico (Archivo General de la Nacion). In addition, datable information in a number of publications listed in the above-mentioned book.
The entry of the individual settlements on the map is based on the first foundation. If a settlement area was abandoned for less than ten years, this was not taken into account.
Criteria for dating of settlement:
1. Written mention: the "Merced" documents (= "grant" documents) governing the allocation of land provide important points of reference. In many cases, it was not possible to take account of the fact that the first settlement did not take place until some years after the allocation. In most cases, the land would have been colonised relatively soon as the governor was empowered to re-possess land still uncolonised after a period of three years.
2. With the Merced areas of the 18th century relating to around five settlements, it was assumed that the foundation of a settlement took around two years and that the ground was occupied piece by piece. This figure was deduced from the sequence of Merced allocations in relation to the number of settlements in the colonisation phases.
3. The criterion given in 2 above can only be used when all the settlements belong to a planned type of settlement (in particular fields divided into wide strips), and common planning is apparent. If several types of settlement exist and no definite names are mentioned in writing, the basis is less certain.
4. This applies in particular to the irregular small farm groups and block fields in the large Merced areas of the 19th century. In these cases, points of reference are provided only by the censuses, which frequently included wide areas and did not always mention individual settlements by name. In these cases, the dates of foundation were distributed evenly over

the period between the granting of the mercedes and the appropriate census date (1850 or 1860).

5. Forms whose dating basis is too uncertain, do not appear in the figures. These are relatively few in number (approx. 5 - 10%).

6. Outside the area shown, there were only very few places of settlement. The migrations between 1692 and 1700 were not entered as these involved mainly people who used Santa Fe as a staging point only, but who came from Mexico or El Paso. Also, the indian pueblos and missions were not shown from 1692, but only from 1700, as in many cases re-settlement took place immediately after the Reconquista.

7. Of the settlements in the border areas, especially in the north (Conejos, San Luis), some were only founded shortly after 1860. For more details on the settlements founded after the colonisation period, i.e. after 1860, see NOSTRAND 1995.

Fig. 11:
Source: 1975 (fig. 25, p. 70). The sources used by me (historical plans and documents, literature data, aerial photographs, field work) are listed here (see also fig. 10). An important aid in identifying the type of settlement are the irrigation ditches dug during the settlement. Without these, definite classification would have been impossible in many cases. The ditches represent a stabilising factor in the development. Land consolidation was carried out wherever roads and railways were built, but these had no effect on the types of settlement.

Fig. 12:
Source: 1997 (fig. 12, p. 74). The graph is based on field work, mapping of the field houses (see fig. 9).
Through the position of the field houses, it was possible to determine which parts of the potential field land was actually used at a particular time. Many houses were occupied over several (ceramic) periods. In all, it proved possible to assign around 1000 field houses to a certain period (multiple use counted accordingly). In order to obtain a cartographic picture of the rotation in field utilisation, the following steps were necessary (1997, page 165):

1. Compiling a 16-part compass rose in order to define in which direction (with reference to the main pueblo), i.e. in which sector the ruins of the field houses are located.

2. In order to eliminate statistically the edaphic differences (between favourable and unfavourable parts) in the land, it first had to be determined how many of the datable field houses were distributed over each sector. The average number of field houses existing in each sector was then calculated, thereby achieving the deviation of the actual distribution from the average distribution for each sector. In each case, this can be expressed by a factor.

3. The number of field houses for every sector and period, then had to be determined and the figures obtained multiplied by the appropriate factor. In this way, the statistically adjusted number of field houses in each sector for each period was obtained. The adjusted figure appears in the drawing.

Fig. 13:
Source: HÄGERSTRAND 1952, p. 3-19. fig. 1.
Hägerstrand divided the land studied into a grid of hexagonal cells, the so-called "observational cells", thereby using the percentage figures as the basis for the adopters.

Fig. 14:
Source: 1981 (fig. 13, p. 88).
The choice of the subjects, time intervals and statistical treatment depend above all on the available material; an optimum representation corresponding to the questions of interest was attempted.
The periods were defined using the works of writers, architects and painters. The dates of publication or production were classed according to decades. Smoothed over 3 decades.
In order to detect and determine the processes, the increase was represented in each case, and not the state (e.g., the increase in production and not the production figures themselves). Otherweise S-shaped graphs would have resulted.
In order to achieve comparability, the respective maximum values of time, i.e. the greatest rates of growth were taken as equivalent to one hundred (1981, p. 276).
The data are taken from a number of works containing concrete information (1981).

Fig. 15:
Source: 1990 (fig. 2, p. 24).

Fig. 16:
Source: 1981 (fig. 7, p. 66).

Fig. 19:
Source: 1990 (fig. 7, p. 31).

Fig. 20:
Source: 1997 (fig. 7, p. 58).

Fig. 21:
Source: 1999 (fig. 19, p. 71).

Fig. 22:
Source: 1997 (fig. 10, p. 68).

Fig. 23:
Source: 1997 (fig. 11, p. 70).

Fig. 24:
Source: 1987 (figs. 3 and 4, p. 115).
The needs of the fast-growing towns meant that a large proportion of the goods required had to be brought from other areas, in the same way as goods produced in the towns had to be sold in other areas, or even through international trade. In spite of this, the ring structure was preserved and in some cases even became more prominent. Map (a) and diagram (b) cover the utilisation activities which were carried out within the context of the task processes of the city-umland population, i.e. within the context of mankind as a society. The unspecified areas in the town area include activities carried out by mankind as a species (e.g. parks for recreation, hospitals, restaurants, hotels etc.).
a) The map:
The radial scale has been distorted according to the formula for wide-ranging effect (see section 2.4.3.1, no. 15) in such a way that each ring has the same width. If one moves from the centre to the periphery, the exponential diffusion with the increase factor k (according to formula no. 5, section 2.2.3) receives a potential growth a:
Step 1: $y_1 = y_0^a * k$
Step 2: $y_2 = y_1^a * k$
In the analytic representation, the radial scale is as follows:

$$y_n = y_0^{a^n} * k^{\frac{a^n - 1}{a-1}}$$

In the case of the city-umland population Saarbrücken, the values used are $(y_0 = 0{,}6; \quad a = 1{,}06 \quad k = 2{,}1)$. The centre is the crossroads Bahnhofstrasse and Sulzbachstrasse.
b) The diagram:
Around this centre, circles were drawn according to the radial scale. The individual land-use rings (1987, p. 113):
I. The demand for products from the superior environment is received (perception). The retail trade appears as an institution.
II. This information is passed to the manufacturing units (determination). Private offices, concern administration, banks etc. appear as institutions.
III. The individuals processing the information receive the instructions as workers (regulation). At the interface between the requirements of the system and those of the individual, public administration appears as an institution. It assures the general conditions.
IV. Passage of the information to the outer area. On the other hand, the products from the outer area are passed to the inner core area. The residential belt becomes established here.

V. The raw materials are processed to form products (dynamisation). Industry should be mentioned as an institution.
VI. The raw materials are transported to the place where they are processed (kinetisation). Short-distance traffic is an important institution here.
VII. The required raw materials are taken from the inferior environment if the resources permit. Agricultural units are located here, at the periphery of the city-umland system (stabilisation).

Fig. 25:
Source: 1981 (fig. 23 and p. 281) and 1997 (fig. 17 and note 76). These sources are intended as an indication for reference purposes only. They are based on historical publications which permit evaluation of time sequences. In the diagram, the strongest growth was generally taken to be equivalent to one hundred to make comparison possible.
Note on the individual graphs (about the institutions see section 2.5.3.1):
Perception: The data on the lives of Greek and Roman authors (philosophers, poets, grammarians, mathematicians, scientists, orators, geographers, historians) were used as indicators for the institutions of art and science. Only data are used which can be fitted into periods of time each covering 20 years. This was simplest in cases where the biographies are known (dates of birth and death). However, in many cases, only information such as "around 300" or "beginning of 2nd century A.D." is given. In these cases, two periods each covering 20 years were entered which correspond to this information (i.e. for the above examples, 280 - 320 and 100 - 140). When only the date of a certain work by the author is known, this was used. On the other hand, no entry was made when only the century is known. The results were smoothed for 3 periods, i.e. a total of 60 years. In all, approximately 1500 single dates referring to around 600 persons were used in this one graph reflecting perception.
Determination: Areas of Christian conversion (areal growth).
Regulation: Formation of states in Central and Western Europe (Franconia, Holy Roman Empire. Areal growth).
Organisation: Emergence of cities in Central Europe.
Dynamisation: Acquisition of colonies outside Europe. Areal growth. Ten year averages. The number of new colonies acquired by political means on politically foreign ground, taking possession by means of peace treaties etc. The setting up of trading posts is assessed in the same light. The surface area involved was not of major importance for inclusion here; particularly for early centuries the area controlled cannot be established accurately. Moreover, the size of the area under command does not necessarily reflect the importance of the colony (cf. military bases are usually only a few sqare kilometers in size but of great strategic value).

Fig. 26:
Source: 1981 (fig. 14 and p. 276/7). The sources used by me are listed here. The graphs are based on historical and economic studies and handbooks. They are quoted in the above work. 10-year averages, unsmoothed. To assure comparability, the maxima of the growth rates (foundation dates) were regarded as being equivalent to 100.

Fig. 27:
Source: 1981 (fig. 20 and p. 280/1).
The graphs are based on the evaluation of historical and geographical studies quoted in the above work. The number of newly established settlements was taken as the basis.
Average of 10 years and maximum of the respective curves set = 100.

Fig. 28:
Source: FRIEDRICH, H. and BRAUER, U. (1985).

Fig. 29:
Source: Landesarbeitsamt Rheinland-Pfalz-Saarland. Statistisches Sonderheft 1/1991.

Fig. 30:
Source: 1997 (fig. 13, p. 81).

Fig. 31:
Source: 1981 (fig. 22, p. 187).

Fig. 32:
Source: 1993 (fig. 23, p. 321).

Fig. 33:
The review of the processes in an ecosystem was already published in ELLENBERG (1973), Fig. 1, p. 3.
This graph was used in simplified form by
KLUG, H. und LANG, R. (1983), Fig. 22, p. 85.
Fig. 33 is based on this simplified graph.

Fig. 38:
Source: 1999 (p. 25-28).

Fig. 39-44:
Source: 1999 (pp. 20, 28, 43, 70, 90, 111). Here, the stages of bundling, alignment, interlacement and folding are presented in detail.

Fig. 45:
Source: 1999 (fig. 30, p. 119).

Glossary

Acceptance: (According to the process theory) 2nd stage of the basic process.
Action motion: see movement.
Action project: see movement project.
Adoption: In non-equilibrium systems, the 1st stage of the main process in which the stimulus (information) is received and prepared for the production (first part of the induction process).
Alignment: 2nd stage in the emergence process. Here, the previously bundled systems and their former process structure are prepared for a task in the process sequence being formed for the system of higher complexity, i.e. they are aligned for the new system.
Artefact: A product made by man for improved adaptation to his environment, for acceleration and specification of actions and processes, for presentation etc. In the process theory, we distinguish between immobile ("earth-bound artefacts") and mobile artefacts ("media").
Atoms, sphere of: Sphere in the universal system (in the microcosmos, in the 4th sphere, seen from above in the hierarchy. Probable task: organisation.
Autopoietic system: System of the 6th stage of complexity. It reproduces itself materially within the universal system. Example: living organisms, molecules, atoms, solar systems.
Basic process: Smallest process unit consisting of 4 stages (from a geometrical point of view). Input (from the environment) - acceptance (in the system) - redirection (towards outlet) - output (into the environment). The content of the stages materialises differently according to the type of process at the different levels of complexity.
Biosphere: Sphere in the universal system. The biosphere (in the spatial sense) is identical with the global ecosystem (in the structural sense). Its position is in the transitional area between macrocosmos and microcosmos (in the macrocosmos the 7th sphere seen from above, in the microcosmos the first sphere seen from above). Probable task: stabilisation resp. perception.
Bonding level: System horizon and element horizon in flow-equilibrium and non-equilibrium systems exist according to their exposure to the flow of information and energy between the superior (energy-demanding) and inferior (energy-supplying) environment, each possessing two bonding levels.
Bundling: 1st stage in the emergence process. Here, the systems of each lower complexity level with their process structure are combined or bundled for the new system of higher complexity being formed.

Carrier: The material skeleton (hardware) of the system which gives the links and processes their stability. Thus, for example, the systems, processes, hierarchical structures and spatial links receive their stabilising framework from their substantial carriers (e.g. matter, populations, institutions).
Cell: Autopoietic system, according to the process theory, an element of a living creature in the biosphere (as part of the micro cosmos). See living creature.
Characteristic group: Statistical group of individuals, which, through 1 characteristic e.g. 1 task, obtains its specific peculiarity. Typical of equilibrium systems.
Chemosphere (chemical sphere): Sphere in the universal system (in the macrocosmos, in the hierarchy 6th sphere from the top). Probable task: kinetisation.
City-umland-population: Population (non-equilibrium system) of mankind as a society, belonging to the 4th uppermost level of the hierarchy. Task: organisation.
Coherence: The holding together of the elements in a system (e.g. of the individuals in a population) caused by the wish or compulsion to make and maintain contact.
Community: Population (non-equilibrium system) of mankind as a species (primary population) and as society (secondary population), belonging to the 5th uppermost level of the hierarchy. Task: dynamisation.
Compartment: Structurally, a flow-equilibrium system in the flow of energy, given material form by a carrier and earthbound artefacts (e.g. group of organisates which compete with one another).
Complexity: State of being all embracing, interwoven, difficult to comprehend, entangled. The term "complexity" has its roots in the greek "   ", which means to weave or tie together, and in the latin "complico", which means to fold or wind together, i.e. different objects are connected with and arranged around one another in such a way that they yield something coherent which we can study in detail and as a whole. A complex formation can be represented as a system which is composed of many parts and elements interacting with one another, possibly showing co-operative behaviour. According to the process theory, this means a fabric of processes, information and energy are exchanged, the individual flows are channelled but also screened from one another. These flows join to form process sequences which maintain or alter the system. Depending on how strongly the flows of information and energy are interlaced with one another and the extent to which the systems demonstrate independence, we distinguish different levels of complexity. Complexity in its actual sense exists when the system does not react linearly to a stimulus, i.e. when the alteration of a variable does not result in the alteration of the other variables. This normally applies both to flow-equilibrium systems as well as more complex systems.

Control process: In non-equilibrium systems, a process at the 3rd process level consisting of 4 control-process stages. The control process regulates the internal relations of the system, especially between the bonding levels.
Conversion process: The process maintaining and altering the non-equilibrium system. The process transforms energy (matter) into products. It is divided into stages. The induction process with 7 task stages is market oriented while the following reaction process, also with 7 task stages, alters the system. The tasks must be solved in a certain well defined order. In this way, the system organises itself.
Cultural population: Population (non-equilibrium system) of mankind as a species (primary population) and society (secondary population), belonging to the 2nd uppermost level of the hierarchy. Task: determination.
Determination: 2nd task process stage. Decision on further proceeding, i.e. the stimulus is prepared for the system.
Dimensions, system(ic): (according to the process theory): Measurable extension of basic characteristics through which the size of a system or the position of part of a system can be defined. There are four system(ic) dimensions: energy (1), time (2), hierarchy (3) and space (4).
Division of labour: Action projects and flow processes in the production process carried out by individuals or populations (in non-equilibrium systems, hierarchical systems, and the universal system) are divided and then re-assembled according to thematical criteria. They are not carried out by one person after another, but by several persons at the same time. The projects and processes of the various participating workers or populations are adapted to one another in accordance with a plan. The division of labour forms the basis for differentiation, among other things of mankind as a society.
Dynamisation: 5th task process stage: energy is supplied to the elements.
Earthbound artefacts: Immobile constructions and earthworks (buildings, roads, ditches, fields etc.) formed by man.
Ecosystem: Multifarious biotic system belonging to the 6th level of complexity and composed of different types of systems (equilibrium, flow-equilibrium-, non-equilibrium systems, hierarchical systems). Man also has his place within the ecosystem. From the point of view of mankind, the ecosystem is the most important energy resource. The global biosphere (in a spatial sense) is identical with the global ecosystem (in a functional sense).
Elements: 1. (according to the traditional system theory): Separable and measurable material and energetic components or parameters of a flow-equilibrium system. 2. (according to the process theory): parts (solida or inferior nonequilibrium systems) of which the system consists. Depending on system type, with varying degrees of independence in the system compound. Example: individual molecules in a liquid, individuals in their roles in a population.

Elementary process: In non-equilibrium systems, processes of the 4th process level consisting of 4 elementary process stages.
Element horizon: In flow-equilibrium systems and non-equilibrium systems the two lower bonding levels which bind the system to the (energy-supplying) inferior environment. Cf. system horizon.
Emergence: Etymologically, the term "emergence" is derived from the latin "emergo": to come to the surface, come up, appear. Here, it means the transition from one level of complexity to the next higher level. The elements form themselves into larger units without this process being explicable in terms of the elements themselves. In the literature on the subject, the transition from flow-equilibrium system to non-equilibrium system is described as emergence. Here, every transition from a less to a more complex type of system (also from solid to equilibrium system) is termed emergence. These transitions are carried out by the 4-stage emergence processes.
Emergence process: Process containing 4 stages (bundling, alignment, interlacing, folding) which executes the transition from a simpler to a more complex type of system.
Energy: The ability to do work. It occurs in various forms, is bound to material or particles of material (foodstuffs, electrical energy etc.) or to energy fields (electrical fields etc.). Energy can be transmitted, distributed (in flow-equilibrium systems) or transformed (in non-equilibrium systems). In the course of the flow of energy, energy must be supplied to the demander qualitatively according to his exact requirements. It manifests the first system dimension.
Energy flow: Transmission, i.e. distribution and/or processing of qualitatively specific energy or matter containing energy (e.g. products) inside or outside the system. The flow of energy must be channelled and, to avoid dissipation, screened off from other flows of energy. In general, the flow of energy leads from the (energy supplying) inferior environment via the elements and the system horizon to the (energy demanding) superior environment which transmits it in turn to the higher system level. The systems are links in chains of energy transfer. The energy flow is optimised in the flow-equilibrium system (3rd complexity level). Examples are product chains in and between populations and food chains in ecosystems.
Entropy: In non-equilibrium systems (e.g. in populations) energy can only be processed and transformed if it is portioned through internal divisions and barriers. The more differentiated the internal division, i.e. the higher the order of the system, the less risk there is that energy flows are mingled and that energy is lost. In a system where the energy supply is too low, the internal order declines over the course of time, i.e. the distribution of the elements strives towards an equilibrium, and so the entropy increases irreversibly. Thus, entropy is a measure of disorder. The

higher its value, the less the order. In the information theory by contrast, the term entropy is applied as a measure of order. From the point of view of the process theory, we prefer to use the term negentropy. The system can be re-ordered through differentiation, i.e. negentropy can be supplied.

Environments: (According to the process theory):
The completing areas necessary for the existence of systems, divided according to the system dimensions:
1. (Stimulating, energy-demanding) superior resp. (stimulated, energy-supplying) inferior energetic environment.
2. Temporal environment preceding resp. succeeding the process.
3. (Controlling, instructing) hierarchically superior resp. (controlled, complying) inferior hierarchical environment.
4. Spatial environment adjacent to the system or process (acting as an initial locality and/or an envelope).

Equilibrium system: A system in energetic equilibrium with its elements. 2nd level of complexity. This system defines itself by the number of its elements. It responds linearly to a stimulus. It is altered by movement projects (e.g. action projects), it orders itself. Examples: a statistically measurable characteristic group in a spatial context (e.g. members of a profession, commuters etc.).

Ethnic group: Population (non-equilibrium system) of mankind as a species, belonging to the 4th uppermost level of the hierarchy. Task: organisation.

Family: Population (non-equilibrium system) of mankind as a species, belonging to the 6th uppermost level of the hierarchy. Task: kinetisation.

Feedback: With flow-equilibrium systems or more complex systems, regulation of the subsequent course of the process by comparing the supply at the end with the demand at the beginning (e.g. of the induction or reaction process or a process stage).

Fit, accuracy of: Flows of information and energy must connect precisely to one another to avoid noise or dissipation.

Flow-equilibrium system: A system consisting of parts in the flow of information and/or energy, which regulates itself by feedback. 3rd level of complexity. It has tangible form, for example, as a compartment. Information and energy are distributed according to supply and demand. The flow-equilibrium system uses the inferior environment as a source of energy. Between the superior environment as energy demander and the inferior environment as energy supplier, the system is divided into 4 bonding levels. The system maintains or alters itself by means of flow processes and feedback (self regulation). Oscillations are created through a delay in supply (energy flow) in relation to the demand (information flow). Examples: quantities of predators or prey in predator-prey relationships in ecosystems, number of demanding or supplying organisates in markets in economic systems.

Flow processes: The flow-equilibrium system is altered or maintained by flow processes. Distribution process. The 4 bonding levels in the flow of information are passed through from top to bottom and in the flow of energy from bottom to top.
Folding: 4th stage of the emergence process. Here, the second part (e.g. the reaction process) of the newly created process sequence is folded behind the first part (induction process). In this way, the beginning and end of the process sequence are linked with one another in such a way that control becomes possible and the stabilisation of the process can be achieved (i.e. here, the system is created structurally).
Hierarchy: Arrangement of systems in levels. In non-equilibrium systems (individuals or populations) the hierarchy serves to control (through order and compliance) the process sequences. The superior non-equilibrium systems surround and control (usually several) inferior non-equilibrium systems. Manifestation of the 3rd system dimension. It is optimised in the hierarchical system (5th level of complexity).
Hierarchical system: Multiple-stage system, whose hierarchic levels are composed of non-equilibrium systems (sub-systems). The lowest stage is the level of the elements. The hierarchical system serves to optimise control. Order and compliance should be equal to one another. A vertical process holds the different levels together. For example, mankind as a society consists of 7 hierarchic levels composed of populations (at elementary level, of individuals). Each level has a task for the hierarchical system in the vertical process, identified by basic institutions. The hierarchical system creates itself structurally. 5th level of complexity.
Individual: Element in the hierarchical system of mankind as a species (as living creature) and as society (in its socio-economic role). Task: stabilisation.
Induction process: Process in non-equilibrium systems consisting of 7 task stages in which the stimulus is accepted from the superior environment (adoption) and the energy from the inferior environment is transformed according to the information (production).
Information: Message which stimulates a system (e.g. a population) to production, maintenance or alteration of itself. The information content reflects the novelty value (the surprise effect). Information can be processed (in non-equilibrium systems) or passed on and spread out (in flow-equilibrium systems).
Information flow: Passing on and/or processing and distribution of information which is qualitatively specific and therefore screened from other flows (of information and/or energy) in order to avoid noise. It may be demand, order etc. The flow of information generally leads from the superior environment down the hierarchy inside the system to the inferior environment.
Initial locality: Starting point of a stimulus or a process.

Input: (According to the process theory) 1st stage in the basic process. The stimulus is put in.
Institution: (Qualitative) material form of the tasks in a stage of a process in a population or a hierarchic system. In the hierarchy of mankind as a society and as a species, the basic institutions give material (thematical) form the tasks in the vertical process (e.g. religion as basic institution, task: determination).
Interlacement: 3rd stage of the emergence process. Here, the newly formed process sequence is (mathematically) reversed, either from the vertical to the horizontal or vice versa (depending on the type of the new system). In this way, the individual inferior process sequences are interlaced.
Ions, sphere of: Sphere in the universal system (in the microcosmos, in the 3rd sphere seen from above). Probable task: regulation.
Kinetisation: 6th task-process stage, energy is transformed into products.
Living creature, organism: According to the process theory, an autopoietic system, part of the global ecosystem or the biosphere (as part of the macrocosmos; e.g. cell).
Long-range effect: Spatial and temporal influencing of movement (action) projects within the context of an equilibrium system. The intensity decreases with increasing distance from the initial location.
Main proceses: In non-equilibrium systems, processes of the 1st process level consisting of 4 main process stages.
Mankind as a population: Hierarchically the uppermost population (non-equilibrium system) of mankind as a species and as a society. Task: perception.
Mankind as a society: Highly differentiated hierarchical system which has come into being in the course of cultural evolution. The groups of humans and populations are divided up or linked with one another through processes and division of labour. Humans in their roles, through their social and economic involvement, are the essential factor constituting mankind as a society. Secondary populations form the sub-systems, the individuals in their roles, the elements.
Mankind as a species: Hierarchical system which has come into existence in the course of evolution. The man in its capacity as a biological being is the essential factor constituting mankind as a species. Primary populations form the sub-systems, individuals as living creatures the elements.
Market: Economic contact zone between two compartments (flow-equilibrium systems) in mankind as a society and mankind as a species, in which informations, energy and products of the populations (non-equilibrium systems) are demanded, supplied and divided.
Molecular sphere, sphere of the molecules: Sphere in the universal system (in the microcosmos, the 2nd sphere from the top of the hierarchy). Probable task: determination.

Movement, simple: Basic unit of energy transmission (1st level of complexity). A solidum is moved, controlled by the environment. Example: action motion.
Movement project: Basic unit of the processes forming an equilibrium system (2nd level of complexity). The movement project consists of many movements. It is ordered temporally and pursues a uniform aim. Example: action project.
Negentropy: The higher the value of negentropy in a system, the higher the degree of order of differentiation (and the lower the entropy). See entropy.
Non-equilibrium system: Entity in the flow of information and/or energy, composed of parts (elements) remote from energetic equilibrium. Information and energy are transformed, products manufactured. The composition of the elements is heterogeneous, division of labour is characteristic. The non-equilibrium system maintains or alters itself through the conversion process which proceeds at 4 process levels which control themselves hierarchically. Through this differentiation of the process sequence, the non-equilibrium system optimises the time sequence. Examples: biological and social populations, as well as atoms, molecules, cells, organisms which likewise belong to the autopoietic systems.
Organisate: Population (non-equilibrium system) of mankind as a society of the 6th uppermost level of the hierarchy. In the organisate, production takes place in accordance with division of labour. Task: kinetisation. Examples: companies, shops, public offices.
Organisation: (according to the process theory) 4th task-process stage; the system is connected spatially with the inferior (energy supplying) environment. The main process stages of adoption and production or reception and reproduction are linked with one another.
Organism: see Living creature.
Output: (According to the process theory) 4th stage of the basic process.
People: Population (non-equilibrium system) of mankind as a species, belonging to the 3rd uppermost level of the hierarchy. Task: regulation.
Perception: 1st task-process stage: acceptance of the stimulus from the superior (energy-demanding) environment.
Planets, sphere of: Sphere in the universal system (in the macrocosmos, 5th sphere from the top in the hierarchy). Probable task: dynamisation.
Population: Carrier of a non-equilibrium system in the context of mankind as a species (primary population) or mankind as a society (secondary population). Populations consist of individuals who co-operate with one another on the basis of division of labour. They are spatially ordered and delimited, are distinguished by qualitative definability and have a certain task for mankind.

Primary population: Population (non-equilibrium system) of mankind as species (e.g. tribe, people, family). The individuals, as living creatures, are the elements.
Product: Product with a certain content of information and energy supplied by populations as a result of the induction process. It is demanded by the superior environment and must fit exactly into the flow of energy.
Production: In non-equilibrium systems, the 2nd main-process stage in which energy is converted in accordance with the stimulus (information) (second part of induction process).
Process: The term "process" is derived from the Latin "processus" which means proceeding, progress or from "processio" which can be translated as "advance".
1. In the flow-equilibrium system (possibly wave-shaped) diffusion process (e.g. spread of an innovation). The flow-equilibrium system is changed from one state to another (changing process).
2. In the non-equilibrium system (e.g. population) identical with the conversion process: sequence of stages arranged in a certain order with differing tasks in the flow of information and/or energy. It serves for production (e.g. for the market) and maintenance or change of the system size and/or structure. Through the division of labour and the differentiation of the course of the process (prozess sequence) the utilisation of time in the system is optimised.
3. Conserving and changing process in the various types of system (e.g. flow-equilibrium and non-equilibrium systems). Either only the quantity of the elements (and sub-systems) is preserved or changed (size-conserving or size-changing process), or the structure (structure conserving or changing process).
4. Main, task, control and elementry process (see appropriate definitions).
5. Emergence process (see appropriate definition).
Process level: Within the non-equilibrium systems, the main processes, task processes, control processes and elementary processes are carried out (depending on the system dimensions). The processes at the lower levels are assigned to the processes at the higher levels. (Previously, I made no distinction between process level and bonding level).
Process sequence: Sequence of task processes in which information and/or energy is converted or processed in the non-equilibrium system or more complex types of system (induction and reaction process).
Process theory: Theory which attempts to explain the flows of information and energy on the basis of the observation that every process is structured within itself and divided into phases, and of analysis of system structures and spaces, and to approach the problems of emergence and complexity in a new way. The starting point was formed by studies of social systems.

Reaction process: Process consisting of 7 task stages in which the non-equilibrium system is maintained or altered according to the results of the preceding induction process. The stimulus is received (reception) and the work executed accordingly (reproduction). The self-organisation of the non-equilibrium system takes place in the reaction process.
Reception: In non-equilibrium systems the 3rd main process stage in which the system is stimulated to maintain or alter itself according to the result of the induction process (planning of self organisation).
Redirection: (According to the process theory) 3rd stage in the basic process. Change in the process sequence in the system from inward to outward.
Regulation: 3rd task process stage. The stimulus is passed on to the elements (e.g. individuals). The elements are coupled to the system (e.g. population) by the stimulus.
Reproduction: In non-equilibrium systems the 4th main process stage in which the system is maintained or altered (concretisation of self organisation) according to the result of reception.
Secondary population: Population (non-equilibrium system) of mankind as society (e.g. state, city-umland-population or organisate). The individuals in their roles are the elements. They are related to one another through division of labour.
Solar systems, sphere of: Sphere in the universal system (in the macrocosmos, 4th sphere from the top in the hierarchy). Probable task: organisation.
Solidum: Something created of substance, not divided into elements but identifiable as a form. The solid is moved and/or altered (e.g. by humans through actions) thereby transferring energy.
Space: (According to the process theory) Through its attachment to a system type, through specific qualitative characteristics, through a certain position in a process sequence and in a hierarchy as well as through extension and outer limitatio defined order. Space manifests the 4th system dimension. The shaping of space is optimised in the universal system (6th level of complexity).
Sphere: According to the process theory, the universal system is composed of shells which enclose space and which are arranged hierarchically above one another, the so-called spheres. Each of these is formed by materially and spatially differing types of non-equilibrium systems (e.g. atoms, molecules, organisms, stars etc.). The result is that the universal system is constructed like the skins of an onion, seen from the point of view each non-equilibrium system.
Stabilisation: 7th task process stage. Release of products to the (demanding) superior environment.
State: Population (non-equilibrium system) of mankind as a society, belonging to the 3rd uppermost level of the hierarchy. Task: regulation.

Stimulation, stimulus: A process is stimulated by the input of information (e.g. demand for energy).
Structure: Arrangement of the elements of a whole.
1. The temporal structure of a system is identical with the process structure, i.e. the construction and duration of the process between preceding and succeeding environment.
2. The hierarchical structure is formed in the flow of information between the superior and inferior environment. Within the flow-equilibrium and non-equilibrium systems, the system as a whole is hierarchically superior to the elements. In the hierarchical system and universal system, systems as sub-systems at higher levels are superior to those located further down.
3. The systems and processes also enclose the elements spatially. This is why we speak of a spatial structure.
Substance: The perceptible material, capable of being shaped, transported, combined with other materials. A system or a structure is concretised through substance (see carrier). Every transfer of energy has to rely on substance. Contrary to matter, substance does not have to be structured or shaped.
System: The term "system" is derived from the Greek "   ", which originates in turn from the verb "   " and therefore means something which is an unified whole which is assembled from several parts. Every system consists of a material carrier and possesses a temporal, hierarchical and/or spatial structure. Different types of system can be distinguished: equilibrium system, flow-equilibrium system, non-equilibrium system, hierarchical system and universal system. See appropriate definitions.
System horizon: The two upper inner-system bonding levels in flow-equilibrium systems or non-equilibrium systems which represent the whole of the system in close contact with the (demanding) environment. Cf. Element horizon.
Task: Typologically defined determination of the content of a system, process, or process stage (perception ... stabilisation). It has to be fulfilled in order to maintain or alter the structure of a superior entity (a system, a process).
Task process: The 2nd process level in the non-equilibrium system process, consisting of 4 task process stages in each main process stage. By combining these, process sequences of 8 (through overlapping of the final and initial stages 7) (induction or reaction process) or 16 stages (total process) may exist.
Time: (According to the process theory) Succession of events in a system which is divided up by the process sequence in the course of the flow of information and/or energy. Time manifests the second system dimension and is optimised in the non-equilibrium system (4th level of complexity).
Tope: Smallest non-divisible delimited unit in the flow of energy at the corresponding level of scale, concretised by a carrier (e.g. a department of an organisate) and permanent

artefacts (e.g. work room). Ecotope is the smallest unit of landscape with an internally unified functioning ecological structure.
Tribe: Population (non-equilibrium system) of mankind as a species, belonging to the third and/or fourth uppermost level of the hierarchy. Task: regulation and/or organisation.
Universal system: (According to the process theory) The whole of the universe composed probably of 16 spheres (or 13, due to overlapping) in the macro and microcosmos. 6th level of complexity. The spheres are distinct from one another materially and spatially (e.g. the sphere of the molecules from the biosphere) and have their specific task as elements in an overriding process sequence. Materially, the spheres are composed of autopoietic systems (e.g. molecules, organisms). A hierarchical order exists. The biosphere has the position of an intermediary between the microcosmos and the macrocosmos. The spheres of the macro and microcosmos are linked with one another functionally and spatially in pairs in such a way that the autopoietic systems in the microcosmos are the elements of the autopoietic systems in the macrocosmos (e.g. the cells are the elements of organisms, molecules the elements of chemical systems). Thus, the universal system creates itself as a substantial and spatial whole.