2.3. Flow process and flow equilibrium system

2.3.0. Instead of an introduction: The textile factory in the flow of energy

The textile factory was integrated energetically in its environment. It received a demand (from the market) and attempted to satisfy it by supplying the products demanded. In order to do this, it required, in addition to labour, raw material and energy. Broadly speaking, this means that the textile company was located in the flow of information (demand) and energy (supply).

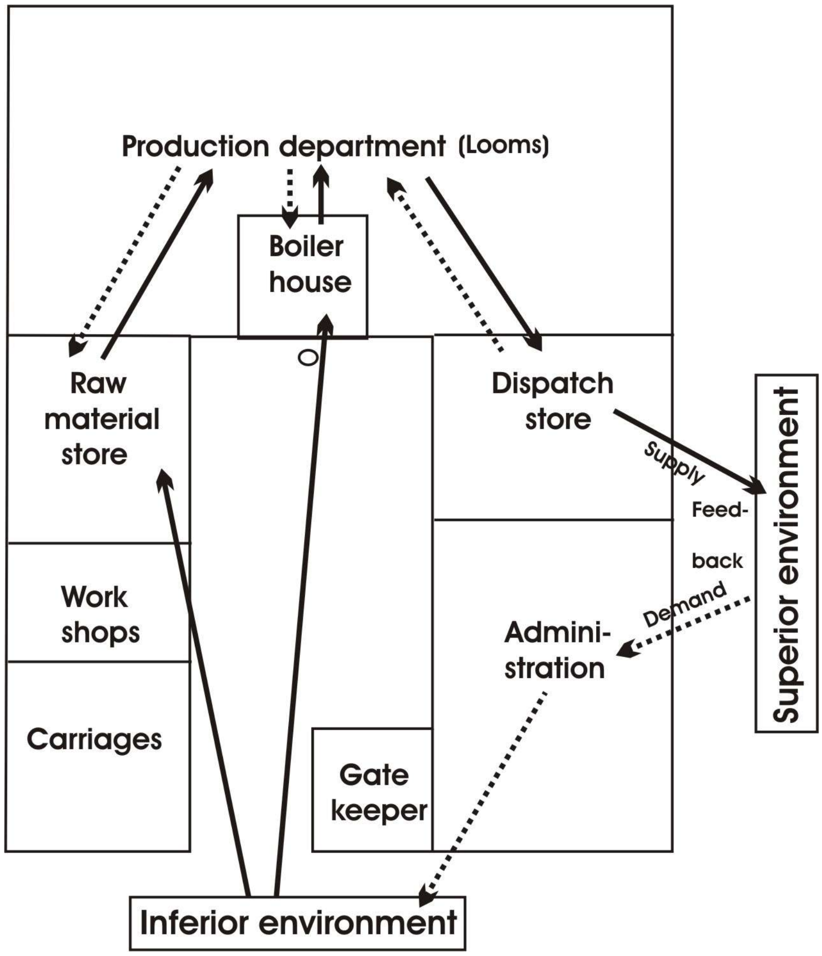


Fig. 34:
The textile company in the flow of information and energy (demand and supply).
Dotted arrows: flow of information. Extended arrows: flow of energy.

Moreover, it was in competition with other companies supplying similar products. Together with these, it formed (through its products) an objectively definable unit of a higher order. 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 and organisations. This is the "inferior environment".

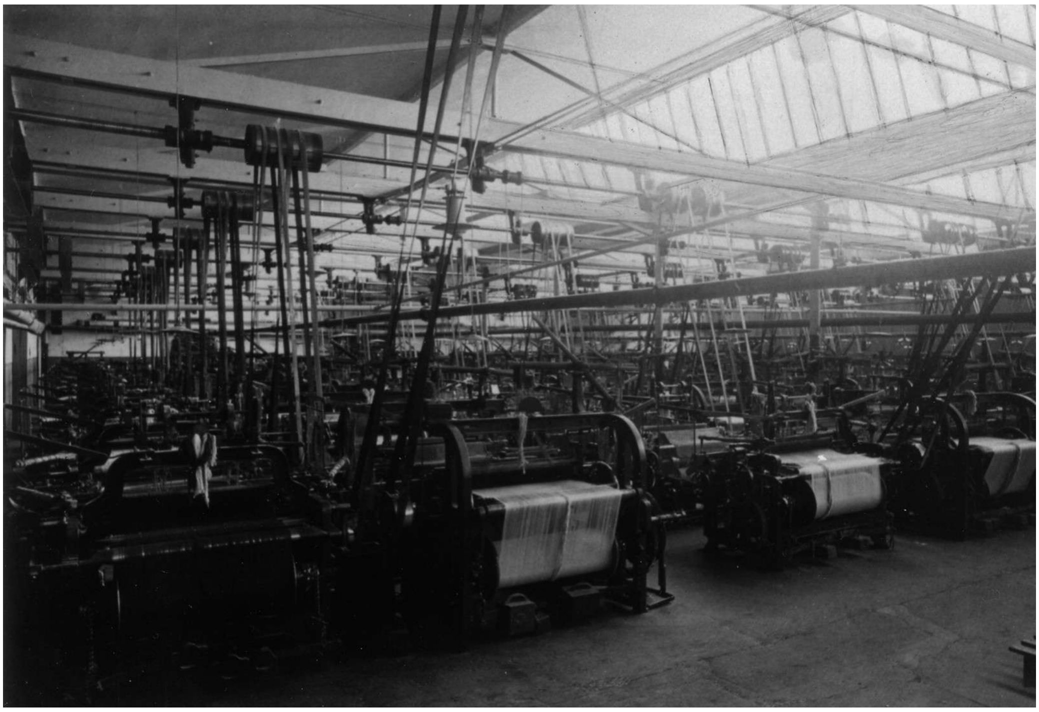


Fig. 35:
The machine room of a cotton-weaving mill in the year 1927.
Example of a department in the factory. Transmission of power centrally via mechanical arbours and drive belts. This is a striking example for the contact between boiler house and production department with its weaving looms.
Reproduced with kind permission of the Gütersloh city archives.
(Source: See "Notes on the figures".)

The "whole" of the textile companies (weaving mills) of a region formed a "compartment". This term originates in the field of ecology (ELLENBERG 1973, p.3). A formation of this kind is distinguished by a material uniformity like the characteristic groups of the equilibrium systems (see section 2.2.1.1, pp.37). The single textile factories are the elements. Their number may vary according to market situation.

Within the textile company, the jobs (or action projects) were thematically ordered and, as already seen (see section 2.2.0, p.35), 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. In this way, each department receives demand from other departments (flow of information), and, in response to the demand, supplies the demanded product, information or goods (see fig. 34). From the point of view of the company, the departments were sub-systems, parts of the organisation.

However, taken individually, the departments could also be regarded as small compartments, similar to the large compartments which represent the entirety of the textile mills in a region. But they are one magnitude smaller. The elements belonging to them were the workers with their action projects. They competed with one another. 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 and media used by them (buildings, rooms, equipment) represented the smallest units of utilisation.

Here we are looking at the compartments only in their capacity as receivers of demand (information) and providers of supply (energy). The opening of the systems to the energy environment also opens the systems to the fluctuations of the market and gains access to innovations at the same time. The production department of the textile mill is an example. Originally, the machines were connected with the steam engine by transmission belts via a common drive unit (see fig. 35). 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. Through constant effort, these systems can maintain themselves between supply and demand in the environments.

To fulfill its tasks, the company was (as described above) a clearly delimited unit which was internally ordered in such a way that it could organise itself. That was its intended purpose. We will return to this subject in the next section (see section 2.4, pp.119).

2.3.1. General considerations

2.3.1.1. System and process:

Large and small compartments:

From the above remarks, it is convenient to distinguish between large and small compartments (see fig. 36).

In the small compartments of the textile factory, the action projects (see section 2.2.1.1, pp.38) are bundled. In general, seen from outside, these are small areas which are uniformly utilised within themselves. Besides the departments in companies, small compartments include e.g. rooms in a house (such as kitchen or living room; see fig. 18) or topes (see section 2.3.2.1, p.96) like cultivated fields in agricultural areas (see fig. 59) or ecotopes in the landscape (see fig. 17).

Unit	Structural position
Larger compart-ment (e.g. market)	System
Factory	Element
Smaller compart-ment (e.g. depart-ment in a factory)	System
Individual (in his role)	Element

Fig. 36:
Large and small compartments as structural units. The factory as an example.

The uniform utilisation appears to be perfectly natural, but it is necessary to take a closer look. In the case of the small compartments, the individual action projects can be conveniently joined together and channeled in this way. To allow the small compartments to fulfil their purpose as efficiently as possible within the company, they are equipped with various types of technical equipment (office machines, looms etc.). Then, the events and processes which occur in the small compartments depend on the information required for its task (e.g. the demand from the company management as the "superior environment"). Moreover, the small compartments 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.

Compartments must satisfy the demand through their supply with the assistance of efficient equipment. Media and earthbound artefacts facilitate the processes and the adaptation of the systems to the necessities of the environment (see section 2.1.1.1, p.18). To secure the supply of energy, the environment supplying energy becomes involved. For its part, it is interested in joining up with the system because it is dependent on the demand. In this way, supply and demand unite and strive to achieve an equilibrium within the flow of energy.

We are dealing with a certain type of process and system. Whereas temporal (and spatial), i.e. horizontal links make up the equilibrium processes (or movement resp. action projects) and equilibrium systems, for this type, it is the energetic vertical connection between the demanding system (e.g. the factory) and the source of raw material and energy (e.g. from the supplying companies).

What applies to the small compartment, also applies for the larger compartment (e.g. a group of textile factories). On the one hand, it must have access to the inferior environment supplying the energy (e.g. the raw materials delivering companies). On the other hand, the system also supplies its (demanding) superior environment (e.g. the market), thereby creating a chain of demand and supply. Thus, 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. The systems are parts of a chain of flow equilibrium systems which are coupled to one another through these flows.

In general, each system tries to maintain itself as an entity. 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". Thus, although the systems are capable of delimitation, they are open from an energetic point of view, i.e. they have input and output relationships with the outside, the environment.

Systemic explanation:

These relationships cannot be explained by the causal method or the functional (or hermeneutic) method. Through the dependence of the systems on the environment and the freedom of decision of the individuals as the elements in the systems, probabilistic links are usual because the reactions of the systems in the environment cannot be determined. Thus, in the

1950s, probabilistic models were used in sociology and human geography, such as had been common in the natural sciences for a considerable time. Surveys provided the basic data necessary.

In subsequent years however, it was realised that this often provided only very general guidance, and in many cases only a slight improvement on deterministic models. In order to obtain more accurate information, it was necessary to examine the system structure. Examinations based on the system theory, such as those developed in the fields of biology (v.BERTALANFFY 1950), mathematics (WIENER 1948/68), economy (FORRESTER 1968/72) and later geography (BENNETT and CHORLEY 1978) make some progress possible (see also section 2.4.2.1, p.167). Indeed, a precise examination of the flows and the links between the individual compartments is required. The flows of material and energy must be measurable, e.g. food or chemical substances in ecosystems, sums of money, goods, raw materials in economic systems etc. These flows can be depicted in structure diagrams. Besides these, flows of information which determine the demand also have to be taken into account. They take effect particularly in retroactive loops and control the flow of materials etc.

Systems reflect the situation of a moment. They change and are different at different times. Changes in the input-output ratio are accompanied by changes in the system relations. The different system states can be understood by means of simulation, thereby achieving an image of reality. This implies the possibility, through modifying individual components, of showing a way which may lead to an improvement in actual conditions if this is what is being sought.

The system theory therefore deals with structures which are already very complex and which consist of several compartments (often designated as "elements" by system theoreticians). However, for the purposes of this study, we will (for the present) restrict ourselves to what happens in the smaller and larger compartments in order to understand the "mechanisms" more closely and to gain an insight beyond the purely superficial input-output relations. In particular, we are interested in system-internal flows of information and energy between demand and supply, the regulation of these flows, and the oscillations and the spatial changes caused by the processes of diffusion.

With the equilibrium processes (see section 2.2.1.1, pp.40), an internal division into stages has taken place at element level (movement projects) depending on the chronological sequence. The equilibrium processes are made up additively of such movement projects. Here the situation is now different to the extent that the system as an entity receives a weight of its own (as mentioned already). Although the elements (individuals) still have their own interests, as parts of the system, they are subordinate to the whole. The flow of information and energy rooted in the superior or inferior environment requires an internally controlling hierarchy.

Thus, 2 structuring tendencies should be distinguished which find their expression in process trains. The first process train organises the internal structure while the second process train controls the flow of information and energy stemming from the environments.

1st process train:

The internal hierarchy, bonding levels:

Let us try to understand what happens in the system (e.g. compartment of textile factories) between the superior and inferior environment. First of all, the system forms a link in a chain of systems. The demand comes from the superior environment, i.e. from (one system or various) systems of the superior environment, and then passes through the system to the inferior environment, i.e. to (one system or) various systems in the inferior environment. From there comes the energy, i.e. in our case, the system 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 systems.

We can divide the entry of a stimulus into the system into 2 stages, which are the equivalent of partial systems. The first partial system covers the system (as a whole) with its elements and is determined by the superior environment (see also section 2.2.1.2, pp.42). The demand is entered into the system and then accepted by it. This is the "system horizon". It is defined by the size, i.e. the quantity of elements and the capacity of the whole of the system. The individual elements have their own interests, they need the demand for their own existence, so they also demand on their part. 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" (see fig. 37). [In the factories, system horizon and element horizon assume, so to speak, the function of employers and employees. The employers must ensure that sufficient demand enters the factories so that the employees can be supplied with work they "demand" for their own.]

For their part, these partial systems are again divided. The system and element horizon are represented in their different capacities. The system horizon as the entirety of the system:
- Input: the information from the superior environment encounters the system. The quantity of the elements is an indicator of the size of the system;
- Acceptance: The system, i.e. the quantity of the elements absorbs the information. The system is limited in its capacity.
The element horizon as defined by the individual elements and their capacity:

- Re-direction: the information is input, the elements themselves are stimulated;
- Output: the elements absorb the information according to their capacity and offer them to the inferior environment as a stimulus.

This is the information flow (energy demand). Here we again recognise the basic process (see section 2.1.1.2, pp.21).

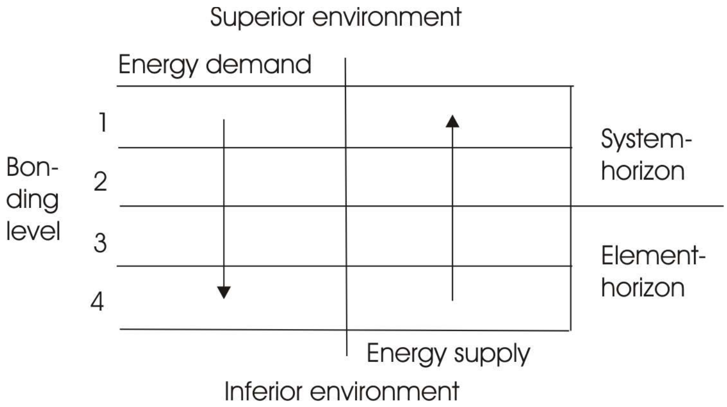


Fig. 37:
The four bonding levels (system horizon: entry and exit, element horizon: entry and exit) in the flow of information (demand for energy) and energy (supply of energy).

The density of the bonds increases from the top downwards, i.e. the information is increasingly bound up in the system and its elements. The four levels are arranged hierarchically one above the other, we will call them "bonding levels". The flow of information with the stimuli takes place from the top in a downward direction, from the whole (system horizon) to the elements (element horizon). A hierarchy is created which allows a control.

The inferior environment with its systems decides independently whether and to what extent the demanded energy (raw materials etc.) is supplied. Then the energy flows from the elements to the system as a whole which supplies the market:
- The elements as such receive energy from the inferior environment (4th bonding level).
- The elements absorb energy (3rd bonding level).
- The system as a whole receives energy from the elements (2nd bonding level).
- The system as a whole releases energy to the superior environment (1st bonding level).

Thus, the system involves the inferior environment.

The system is influenced on the one hand by the energy demand of the superior environment, and this has a special influence on the system horizon. On the other hand, the energy-supplying inferior environment influences the element horizon. The system horizon controls the element horizon by way of the demand/supply-relationship. On the other hand, the elements differ in their possibilities and constraints and are therefore independent up to a certain point. Thus, it may be said of the flow equilibrium system that the whole is more than the sum of the elements (in contrast to an equilibrium system).

At the various bonding levels the information and the energy are distributed. These processes are interpreted as the equilibrium processes. Thus, the processes take place horizontally one bonding level after another within the flow of information and within the flow of energy. In doing so, the elements follow the four stages of the basic process. The process involves the elements at the bonding levels, so that processes come into being at the individual level. This affects the vertical structure (bonding levels) in the system. So the system is moved from one state into another (see section 2.3.1.2, pp.81).

2nd process train:

The contact with the inferior environment, i.e. the demand for and the supply of energy, takes place at the fourth bonding level as explained above. The way in which the system is controlled by contact with the superior environment can be described by the terms feedback, oscillation, diffusion and rotation.

Feedback:

The vertical flows of information and energy have to be coordinated with one another to ensure that the system can keep itself in a flow equilibrium. This is assured by the feedback (see fig. 39).

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

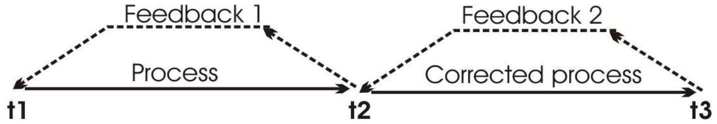


Fig. 39:
Feedback taking the process sequence into account.
t1 the moment at which stage 1 begins, t2 the moment at which stage 1 ends, beginning of the second stage (with corrected process).

("just in time")]. The compartments with the companies competing against one another on the market (superior environment) can only check that the desired goods comply with the requirements of the demand with regard to quality and quantity when they are supplied. This takes place at the borderline between system and superior environment. 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 companies as the elements of the compartment receive the assurance that their supply is accepted. Some companies are perhaps unable to compete and are forced to give up. Thus, selection takes place, the number of companies in the compartment fluctuates. In this way, the system (compartment), i.e. the whole of competing companies as elements 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 (output). Fluctuations take place through the delay intervening between demand and supply. Sometimes too little is supplied and then perhaps too much (see fig. 40).

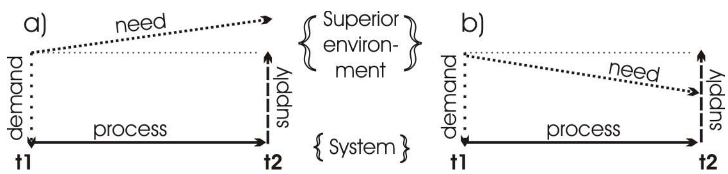


Fig. 40:
Possible tendencies in the development of the requirements of the superior environment (the market) in the course of the process.
a) demand exceeds supply;
b) supply exceeds demand.

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 (see fig. 41).

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; see section 2.3.2.1, pp.103).

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.

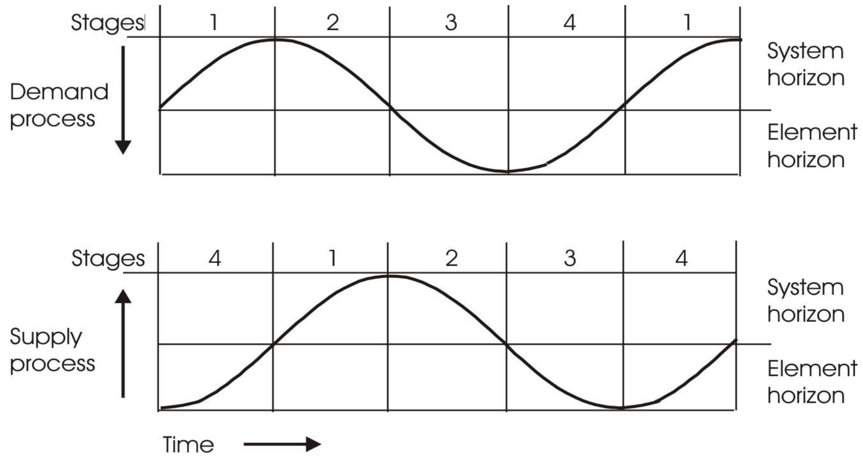


Fig. 41:
Delay in the supply process with reference to the demand process.
The numbers indicate approximately the stages 1 - 4 of the process (see section 2.2.3).

Diffusion:

In a small system (or compartment) like a department, the horizontal transfer of a stimulus is simple. The time factor plays virtually no part. Besides, the departments of the textile mill are dependent on instructions. With the larger systems (like the market), this is not so. In this case, innovations are spread by diffusion, which takes time. When one company adopts the innovation and is successful, the others follow if they do not want to drop behind on the market. This innovation passes from company to company in the compartment. Such innovations are generally spread through neighbourhood contact by being adopted gradually by those interested.

Diffusion assumes a homogeneous structure of the system, since the innovations which are transported by diffusion, have to be adopted by materially suitable elements. An essential condition for all 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),
2. that the system as a whole is ready and able to adjust accordingly (i.e. to diffuse an innovation, e.g. better looms),
3. that the elements are able, after adoption, to put the innovation into practice, 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, i.e. the market. 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 above and section 2.3.1.2, pp.81). Since innovations generally correlate with upward trends in oscillations, they spread over the system in waves.

Rotation:

When an innovation diffuses, the process normally spreads to other areas of the compartment away from the "initial place". However, when the intrinsically homogeneous systems proceed around a centre (e.g. the Thünen rings; see section 2.2.2.4, p.58), the innovations are diffused in a tangential direction (example: proceeding of cultivation around an agricultural settlement; see section 2.6.1.2, p.254). We call this process "tangential rotation" (see fig. 38).

In the case of "irregular rotation" the centres of innovation jump from one population to another, a spatially regulated progression is not recognisable. However, the passage from one to another is often prepared by the preceding population in their area of influence (e.g. through closer trading contacts etc.). In each case, one population becomes predominant as a centre of innovation, which proves to be most suitable for the task in hand for a certain period of time.

The structural and spatial spread of the flow equilibrium system is limited wherever the vertical environmental conditions change, i.e. where other things are demanded from the superior environment, or where too few or no resources are provided by the inferior environment.

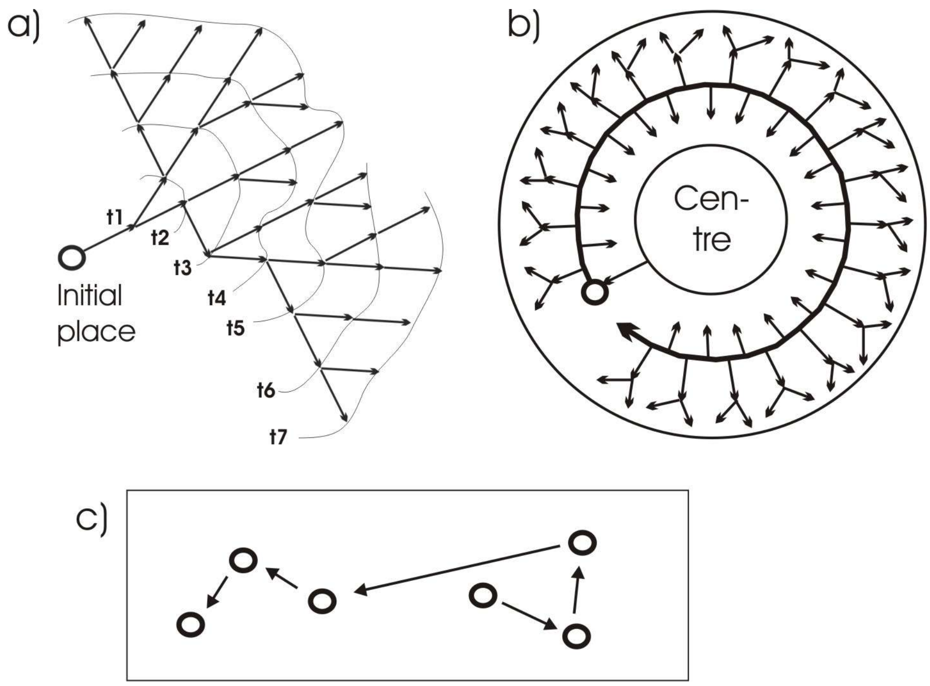


Fig. 38:
Diffusion and rotation. Diagram.
a) Diffusion from an initial site into an outland. t1...n moments in time
b) Tangential diffusion starting from a centre (e.g. a town): tangential rotation,
c) Irregular rotation. The initial sites shift.

As we will see later (sections 2.4.2.1, pp.147, and 2.5.2.2, pp.233), the diffusion of innovations is a type of process which leads to social change, and on a more general scale, cultural evolution.

2.3.1.2. The Model

A suggestion for describing the above mentioned flows mathematically is made below. We follow the flow of information in the system:

1st bonding level:

The demand is entered into the flow equilibrium system. The system defines itself here exclusively as a quantity of elements. These are by themselves, without restriction by a specified system:

1st stage: The demand for energy should be regarded as information which has to be introduced into the system in the same way as energy (see section 2.2.1.2, p.43). Energy and information have to be exchanged between the elements of a system, otherweise it loses its character as energy resp. information. This means that the same laws regarding structure and the ability to stimulate apply to both (EIGEN and WINKLER 1975, pp. 165). In the theory of information, the information content of a message is defined in the same way as entropy from an energetic point of view. The strength of the stimulus is expressed by the information content. Thus, the formula table for the theory of information (SHANNON and WEAVER 1949/76; SCHWARZ 1981) can be used to describe the flow of information or energy. Every single element has to be reached.

The stimulus from the superior environment is entered into the system. The information content may be represented by the formula

$$I = \log r \text{ ,}$$

where *I* is the information content of a message and *r* the number of micro-states. It should be noted that each of the *r* micro-states appears with the probability $p_i = \frac{1}{r}$. Through the selection of the logarithm for the base 2, we obtain the dimension *bit*. So the formula for the information content is

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

The value *I* indicates the stimulus strength.

2nd stage: The stimulus is absorbed in the system. The absolute value must now be opposed by the number of elements. The required relative value *d* represents the extent to which the system, on average, becomes stimulated. c represents all, w the non-stimulated, and c-w the elements becoming stimulated. This produces the formula

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

3rd stage: The stimulus is diffused into the bulk of the elements. The quantity of the elements adopt the stimulus. The diffusion is based on the simple positive exponential equation (discrete form):

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

where *N* is the number of adopters, *n* the number of time steps; *k* is a constant (increase factor).

4th stage: The relation between the new elements (adopters) to all (new and old) elements is asked for. Let us assume that the event that in a quantity of n elements appears a new element 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

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

The individual new elements all occur with the same probability. When the number of tests is high enough, *m* approaches the number of the new elements.

2nd bonding level:

The elements have their position (and function) in the system, and appear as components in a limited system. Each of the elements strives individually to achieve an equilibrium in the system as a whole:

1st stage: The stimulus (information symbol *A*) is conveyed to the elements (information symbol *B*) of a limited system. The probability of the appearance of the symbols *A* and *B* is $p(A)$ and $p(B)$. The probability $p(A) = 1 - p(B)$ applies. If the symbols 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 information content (stimulation strength) is then highest. If however $p(A) = 0$, then $p(B) = 1$ [or if $p(B) = 0$, then $p(A) = 1$]. The 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

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

This is the formula of the "(neg)entropy" (here with 2 categories only) as intended by the information theory (SHANNON and WEAVER 1949/76).

2nd stage*:* The system has a limited number *c* of elements. Of these, w elements cannot be stimulated for a number of reasons, e.g. because they are already stimulated. Thus, $(c - w)$ is the number of elements which can be stimulated. *d* reflects the capacity of the system to absorb stimulae. The lower the number *w*, the more stimulus can be absorbed for each element. If $w = 0$, then $d = 1$. If, on the other hand, $w = c$, then $d = 0$. The graph decreases linearly.

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

3rd stage: The system (under consideration of the stated capacity) adopts the stimulus and changes its state. The diffusion of the stimulus into the quantity of elements of the limited system is performed. 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):

[7a] $$N_n = N_{n-1} + O_n ;\ O_n = O_{n-1} * M_n ;\ M_n = \frac{M_{n-1}}{a} \ adopters$$

Or the development is limited by the capacity of the system as a whole; the "Logistic function" is applied (see fig. 42). Then the size of the system is assumed to be known. The constant *K* defines the quantity of the potential adopters (*a* constant):

[7b] $$N_n = N_{n-1} + N_{n-1} * \frac{K - N_{n-1}}{a} \ adopters$$

In both cases, the graph is S-shaped.

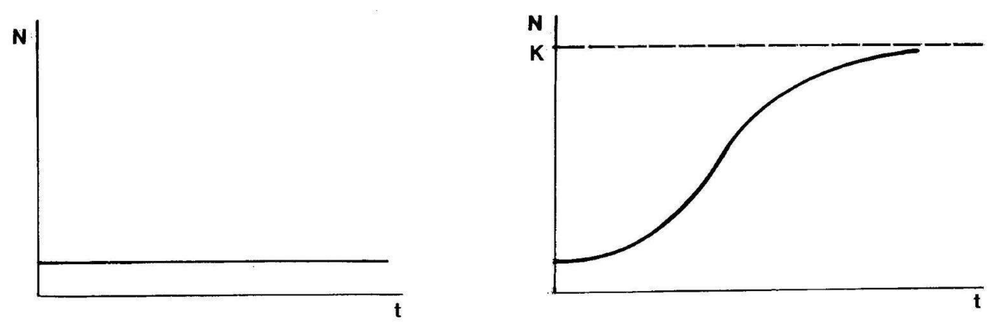


Fig. 42:
Conserving and changing process in the flow-equilibrium system.
In the conserving process (left) the amount of production or the number of elements N remains constant over the course of time, whereas if a change takes place (right, "logistic curve"), the value of N has an S-shaped curve, i.e. 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.

4th stage: The "new" elements (i.e. the adopted quantity of information), now have to be opposed to the "old" elements. Both appear with equal frequency. We will arrange these in a sequence of numbers and place them to two scales (see fig. 43 a). When we push these past one another, the numbers meet one another in pairs. Every meeting means that a new element stimulates an old element. For reasons of simplicity, we will take six representatives of each of the groups and move them past one another in steps, first one each, then two each etc. until all six members of each group are arranged opposite one another. Then the system is stimulated. If we continue to push the scale, the number of encounters decreases accordingly. We can convert this combination into a probability function (see fig. 43 b). So 2 sequences are joined together in the same way as a game with 2 standard 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 symmetrically to a centre $x = m$ (average or anticipated value, for ideal dices 7 points), 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 $k = 0, 1 \ldots m - 2$.

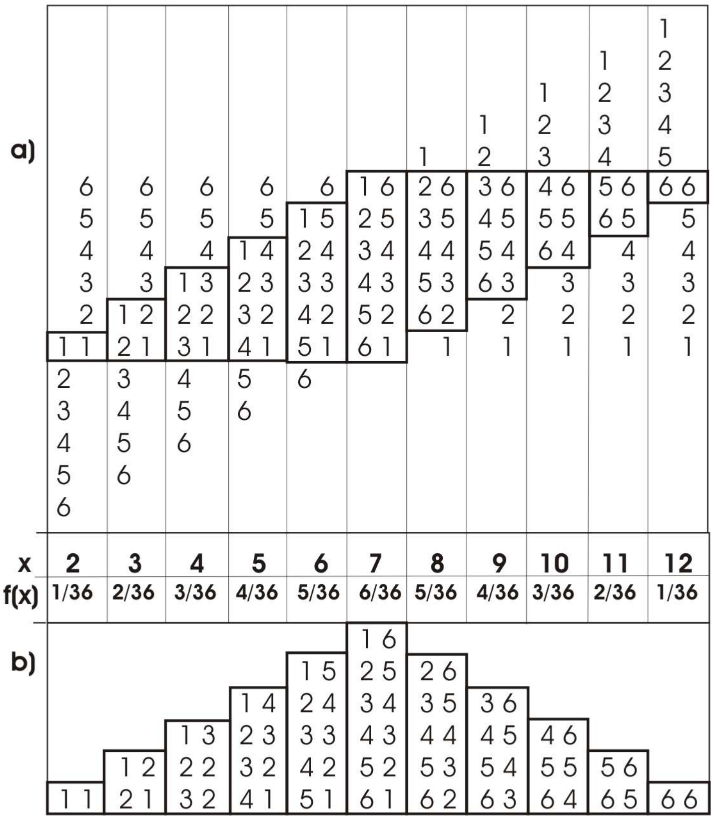


Fig. 43:
Illustration of the probability function at the second bonding level (formula 8).
a) Sum of encounters between stimulating ("new") elements and elements to be stimulated ("old") in a limited system ("framed" sequences of numbers).
b) Sum of the points of two ideal dices. Elementary events. The lefthand number in each case indicates the sum of the stimulating elements or of the first dice, and the right-hand number the sum of the elements to be stimulated or of the second dice.

This results in the probability function:

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

(x = the sum of the elements or points; $f(x)$ = probability)

3rd bonding level:

The elements (or parts of the element horizon) are dependent on the stimulation by the system horizon. But they themselves also strive actively to obtain a place in the flow of information. Thus, the demands of the system (as system horizon, see section 2.3.1.1, p.75) are opposed to those of the elements.

1st stage: The stimulus is put to 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.

Thus, the grouping of the 2nd bonding level is again sub-divided. Information flows in both directions. The factory as an example: 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 symmetric 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 (neg)entropy has the information content (SCHWARZ 1981, pp. 43.):

[9a] $$I = \sum_{i=1}^{i=m} \sum_{j=1}^{j=n} p_{ij} * ld \frac{1}{p_{ij}} \quad bits$$

From this is derived the transinformation which reflects the degree of connection between characteristics *A* and *B.* We must take "noise" into account, because a certain part of the information transmitted is usually lost. When the equivocation is subtracted from this sum, one obtains the strength of the stimulus finally transferred, i.e. the transinformation

[9b] $$T(A,B) = \sum_{i=1}^{i=m} \sum_{j=1}^{j=n} p_{ij} * ld \left(\frac{p_{ij}}{p_i * p_j} \right) bits$$

2nd stage: 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 become stimulated. The system as a whole reacts in the same way as in the 2nd bonding level. The totality of all elements is *c*, *w* elements cannot be stimulated. Thus, in the system, *c* - *w* elements can be stimulated. If we assume that the system consists of *c* = 10 und *w* = 0 elements, the initial value is *d* = 1. At the 1st step (*w* = 1) 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 amount of stimulation per element is

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

(*w* = not to be stimulated, *c* = all).

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 2nd stage), but additionally reduced by a term N_{n-1}/b. The result is a hill shaped graph (*n* is the x-variable):

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

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

4th stage: 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 new 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 function is

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

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

4th bonding level

The system makes contact with the inferior environment, in order to receive energy according to the stimulation. The whole system is now integrated in the flow of information.

1st stage: The demand, i.e. the information is passed from the system to the inferior environment. According to the

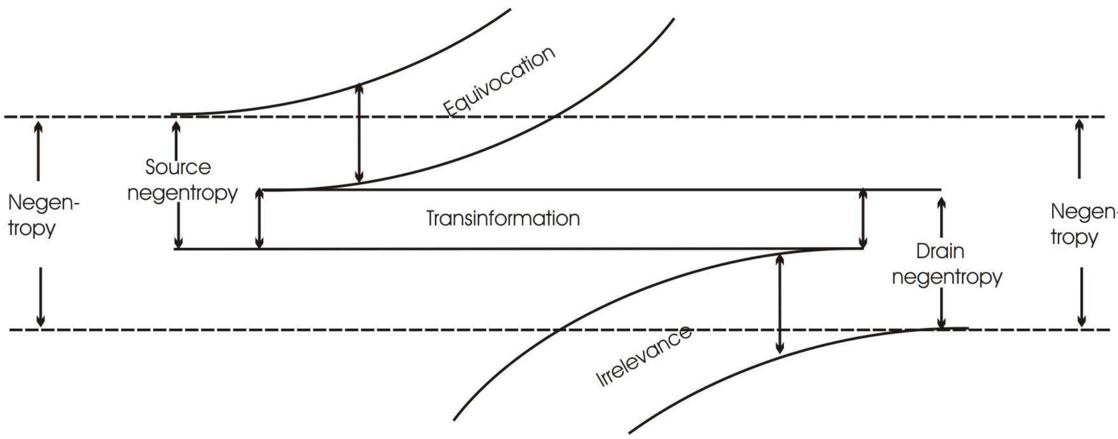


Fig. 44:
Channel model in which various terms of information theory (fourth bonding level) are explained.
After Berger.
Source: See "Notes on figures".

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 (neg) entropy I_S is confronted by the drain (neg)entropy I_D. These can be represented in a table as lines and columns (= asymmetric channel as per information theory; see fig. 44; 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 (neg) entropy and the irrelevance, or of the drain (neg)entropy and the equivocation. The information content is expressed in the following formula:

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

(Indices for the source (neg)entropy $i = 1...m$, for the drain (neg)entropy $j = 1...n$; 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. The equivocation has to be deducted from the source entropy and the irrelevance from the drain entropy (see fig. 44).

2nd stage: The system *A* and the inferior environment *B* influence one-another in their development. The value of *c* again indicates the average number of all elements. We return to the 3rd bonding level (see formula no.10). Whereas in that case the value of the stimulus increases both with part A (system as a whole) as well as with part B (elements), in this case it is different. What part A (the system) gives, is taken by part B (the inferior environment) and vice versa (see formula no. 15 below).

Both system *A* and inferior environment *B*, relate to one another. So, in contrast to the 3rd bonding level, a mean value is sought here. We have to take the geometrical mean:

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

[The formula is reminiscent of the so-called Lorentz Contraction which is used for calculating the transformation of the coordinates and time from one uniformly moved inertial system to another (assuming that the speed of light c is constant) (EINSTEIN 1905/1974, pp. 32).]

3rd stage: 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 stimulus is adopted. The demanded energy itself is supplied afterwards (in the non-equilibrium system at the "production" stage, see section 2.4.1.2, pp.128). System *A* and system *B* are interacting with one another. The elements *N* constitute the demanding (demand transmitting) system *A*, and the elements *M* the demand receiving (and afterwards energy supplying) systems *B* of the inferior environment. Because the providing of the reply (and afterwards the demanded energy) by

$$N_n = N_{n-1} + \frac{N_{n-1} * M_{n-1}}{a} - \frac{N_{n-1}}{b} \qquad \textit{adopters A}$$

[15]

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

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

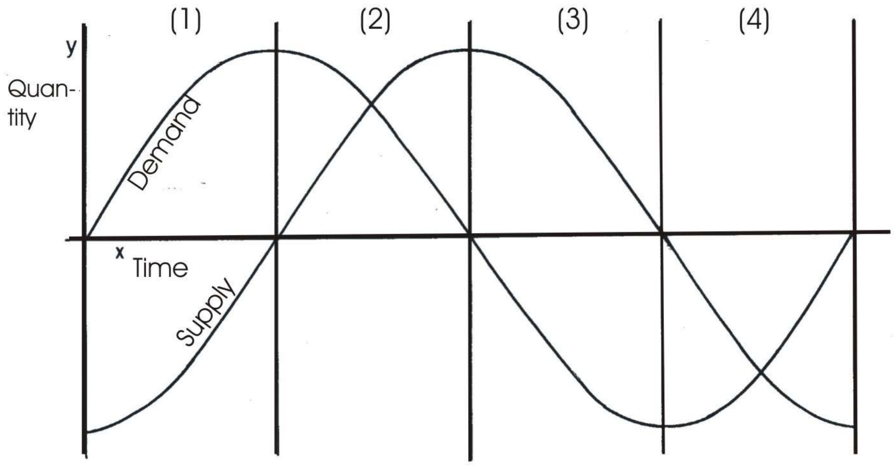


Fig. 45:
Oscillation of a flow-equilibrium system.
The demanders and suppliers (e.g. in a market) stimulate each other mutually. The first group demands energy, the second group supplies the energy. As the supplying group requires time to make the energy available, a delay occurs which leads to oscillations (around a central value, oscillation axis).

the inferior environment needs time, transmitting and receiving are delayed (see section 2.3.1.1, pp.77). Oscillations are created which may be described by the Lotka-Volterra relations (predator-prey relations; LOTKA 1925/56, p. 88. See fig. 45).

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.

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 2.3.1.1, pp.75), 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, pp.17, and 2.1, pp.37).

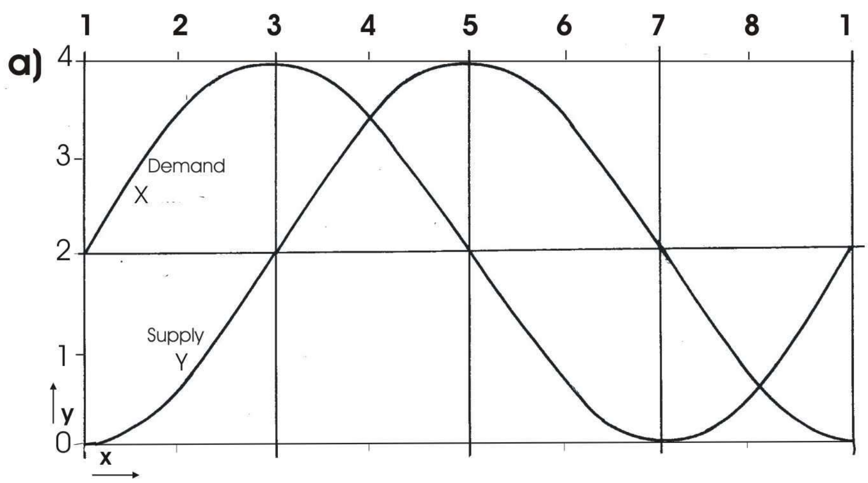
4th stage: The elements of the system *A* and those of the inferior environment *B* appear with a certain degree of probability. The question now to be answered is that of the discrete two-dimensional distribution (variables *X*, *Y*). In the sense intended by the theory of probability, *A* and *B* are independent of one another. This describes the multi-nomial distribution (FISZ 1976, pp. 195). In a sequence of *n* single contacts, the elements of the system appear exactly *x* times (event *A*, random variable *X*) on the one hand, and the elements of the inferior environment exactly *y* times (event *B*, random variable *Y*) on the other hand. 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

$$f(x,y) = P(X = x; Y = y) = \frac{n!}{x!\,y!\,(n-x-y)!} * p_x{}^x * p_y{}^y * (1 - p_x - p_y)^{n-x-y} \qquad [16]$$

As a result, we obtain a circular movement in connection with the oscillations (see fig. 46).



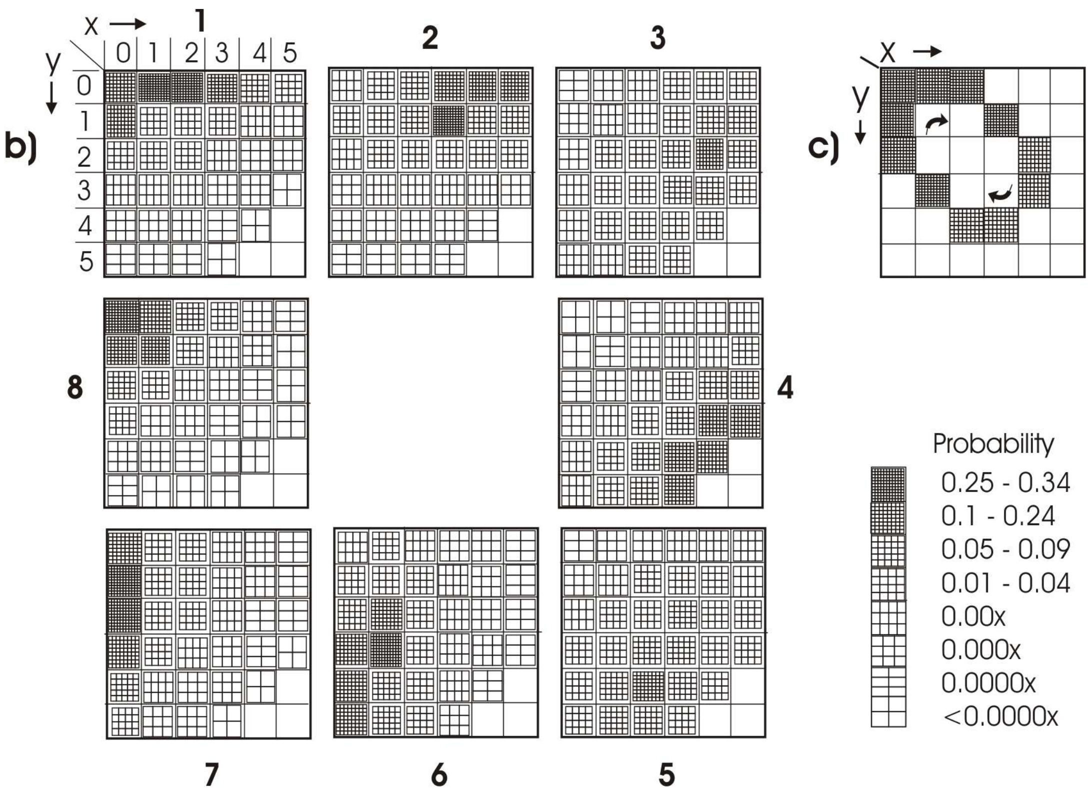


Fig. 46:
Combination Lotka-Volterra-equations and multinomial distribution.
a) The course of the oscillation process according to the interaction between demand und supply (Lotka-Volterra-relations; see fig. 45). 8 cross sections are laid where demand and supply have a special relationship to one annother. b) Probabilities according to multinomial distribution. c) The maxima of the 8 distributions are transferred to a separate grid.

The course of the process:

As has been shown (see section 2.3.1.1, pp.72), energy is demanded by the superior environment and supplied by the inferior environment. The inferior environment, for its part, also demands energy and is supplied by its own inferior environment. In this way, the flow of information (demand) from the top downwards and energy (supply) from the bottom upwards, are conducted through several hierarchic levels. The condition is that the oscillations which make these flows possible, have phases of the same length.

With reference to the continuation of the process, it is remarkable that it is by no means certain that the energy can be supplied in the desired form and quantity by the inferior environment. This cannot guarantee the possibility of "latching into" the flow of information and energy. Thus, when we say that at this level of complexity the inferior environment is involved as a supplier of energy, it is not securely coupled to the contact hinge (fourth bonding level). Otherwise it would mean that the quantity of energy supplied is predictable in the deterministic sense. Instead, the bond is based on the mutual interest above and below the hinge, because only this bond assures the survival of the participants (i.e. the elements). The feedback provides information as to whether the inferior environment has supplied sufficient energy. The result forms the basis for the level of demand in the next round (see section 2.3.1.1, pp.77).

The vertical flow of information and energy from bonding level to bonding level is the first-rank process, and the involvement of the elements at the bonding levels takes place through the processes of the second rank.

The linking of the above described formulae or stages takes place through change quotients which pass the change on to the following stage. At the end of each process at the bonding level, the stimulus (information flow) is passed on to the

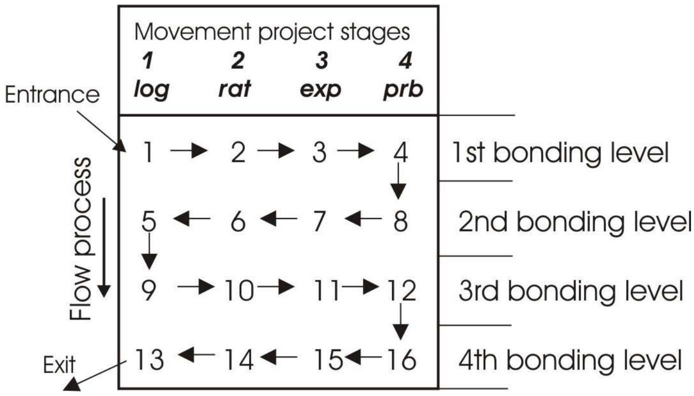


Fig. 47:
The *course of the information flow in the flow process, i.e. the formula sequence in succession.*
The figures representing the individual stages are the numbers of the formulae (see above). Abbreviations: log = logarithmic, rat = rational, exp = exponential, prb = probabilistic.

following process in the next deeper bonding level. At the individual bonding levels, the processes proceed alternatingly in the opposite direction (see fig. 47). In this way, it is possible to join the stages at the beginning or end. The fourth bonding level forms the hinge between the demanding and supplying system (the involved inferior environment). From here, the process leads up to the first bonding level.

The flow of energy proceeds in the opposite direction from the elements to the system, i.e. from the fourth to the first bonding level.

For guidance:

The flow equilibrium systems are thematically defined, i.e. they have a certain task in superior (i.e. economic or ecological) system structures. The systems are composed of similar elements and define departments or topes (e.g. ecotopes) and compartments. They may be, for example, a number of cotton mills. These exist in the vertical flow of information and energy. The flow of information (=demand) comes from the superior environment (market) crosses the system (the quantity of factories), thereby reaching the inferior environment. From here (e.g. the suppliers) energy is acquired and transported upwards to the demanding superior environment (=supply).

In the ecosystem, this corresponds to the predator-prey relationship. Predator and prey interact with one another. Oscillations occur. In social systems the supply follows the demand by about one quarter phase. A number of systems may succeed one another, thereby forming chains. Since both the system as a whole and its elements depend on one another, a flow equilibrium takes place between the two as between superior and inferior environments. The system regulates itself by means of feedback.

Internally, the system as a whole is divided into system and element horizons, which in turn are also divided into two, thereby producing 4 bonding levels. This internal division is controlled from inside (first process train) whereas the oscillations are controlled from outside (second process train). The demand and the innovations are passed on horizontally (e.g. through neighbourhood contact) by diffusion and rotation.

The processes can be described by mathematical formulae which are arranged according to the four bonding levels and reflect the flow of information and energy.

2.3.2. Other examples

2.3.2.0. Instead of an introduction: Flow process as seen by artists

A process is shown here - something which is very difficult for a painter to portray and therefore very seldom attempted. "Equipo cronica" has given us a sequence of paintings showing the stages in the assembly of a crowd (see fig. 48).

Fig. 48:
Equipo crónica: Concentration, or quantity becomes quality. An example of an exponentially growing process.
Source: See "Notes on the figures".

The title "Concentration, or quantity becomes quality" should be taken in a political context. The two artists (originally 3) joined together to form the "Equipo cronica" in 1964 in order to resist the Franco dictatorship whose suppression of human rights and obstruction of progress was at its height in 1966 when the picture was painted (POP ART 1991, p. 274/275). Its message was that only by mass demonstration is it possible to defend oneself against tyranny and dictatorship. The assembly takes on the quality of a signal of the will of the people, and even of insurrection.

Seen formally, what we see is the exponential growth of a process in a flow-equilibrium system which takes its meaning and power from the dissatisfaction of the people with the prevailing political conditions. This message is the information. The anger of the people releases the energy which sets the process in motion.

2.3.2.1. Vertical energy flow

The study of flow equilibrium systems depends on the possibilities available and these are dependent on the constitution of the system. One frequently 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). This includes the study of the behaviour of the elements, the mechanisms of their cooperation. Feedback and oscillations are important objects of research.

The cultivation of a field:

Let us now look at the cultivation of a field. Seen structurally, a field is a small compartment (see section 2.3.1.1, pp.72), but it can only be analysed in combination with other subordinated compartments. They each occupy their own place in the flow of energy. Spatially a field is a piece of landscape which is delimited and unified in its ecological structure and which cannot be subdivided further within the scale concerned. These spatial units are called "topes". The term "tope" originates in the field of ecology (LESER 1976, p. 212; SCHMITHÜSEN 1976, p. 207 called them "Fliesen", tiles; see also ecotopes, section 2.2.2.1, fig. 17, p.48).

Small and large compartments are flow equilibrium systems whose input-output ratio and other characteristics can be studied. Through their own feedback systems, the processes are non-linear, i.e. the output is linked to the input in a non-linear and frequently unpredictable way.

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. The soil 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. He is primarily interested in the ratio of input to output.

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.

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 2.6.1.2, pp.253: "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.

A complex ecosystem:

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

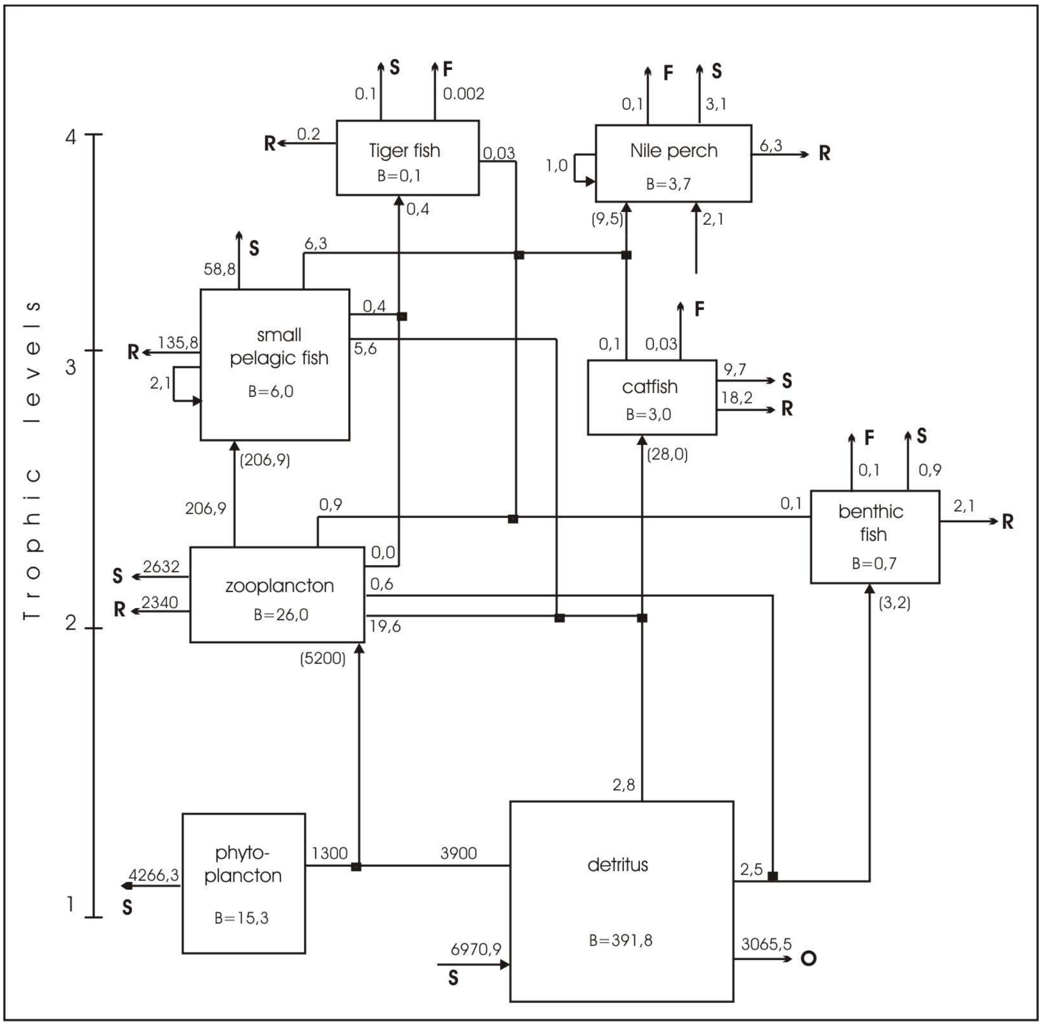


Fig. 49:

Flow diagram of Lake Turkana in Kenya. Example representation of an ecological flow equilibrium system.

Each of the 8 trophic subsystems listed here (compartments represented by boxes) shows inputs (nutrients, represented by arrows) and losses through fishing (F), respiration (R), sedimentation as detritus (S) and other outputs (0).B = biomass.

Subsystems: catfish, Nile perch, tiger fish, small pelagic fish, zooplancton, phytoplancton, benthic fish, detritus.

Source: See „Notes on the figures".

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 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 2.6.2.1, fig. 131, p.272).

The calculation of the flow of energy in an aquatic system is used as an example of a study of an ecosystem (see fig. 49; BEGON, HARPER, TOWNSEND 1996/98, p. 513). Lake Turkana in Kenya is fished. In order to determine the ratio between the annual fishing quota and the nutrient base, the various subsystems of the system were taken together and their significance for the balance of energy studied by means of a flow-equilibrium model. The fishing quota, the food chains and their links as well as the detritus production were then isolated in order to describe the flow of energy or biomass.

In this way it was possible to balance the input into and losses from the compartments. With the help of studies of this kind it is possible to determine with a fair degree of certainty whether fishing rates are sustainable or stocks are being over exploited.

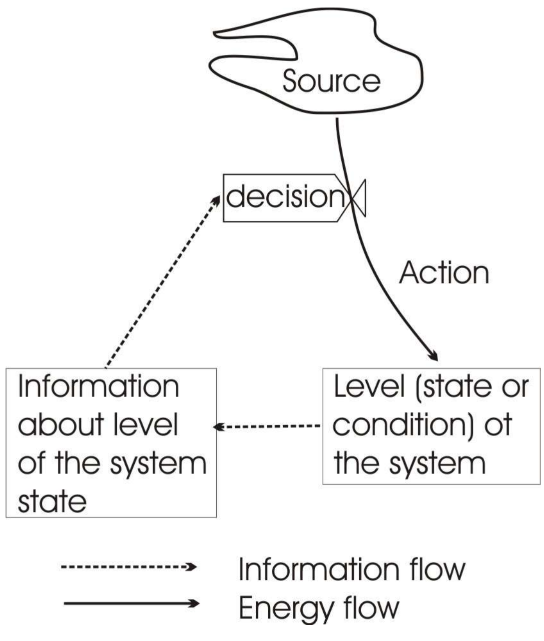


Fig. 50:
The scheme of a feedback-loop. According to Forrester. The process ("action") requires time. The stimulus (demand) is introduced with the "decision". The result (supply) is supplied later to the superior environment. It is here that the feedback begins. If the level ("state or condition of the system") does not correspond to expectation, this information is passed to the "decision" valve. The correction then takes place and is introduced as stimulus for the subsequent process run. Source: See „Notes on the figures“.
A complex economic system, the Forrester feedback model:

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

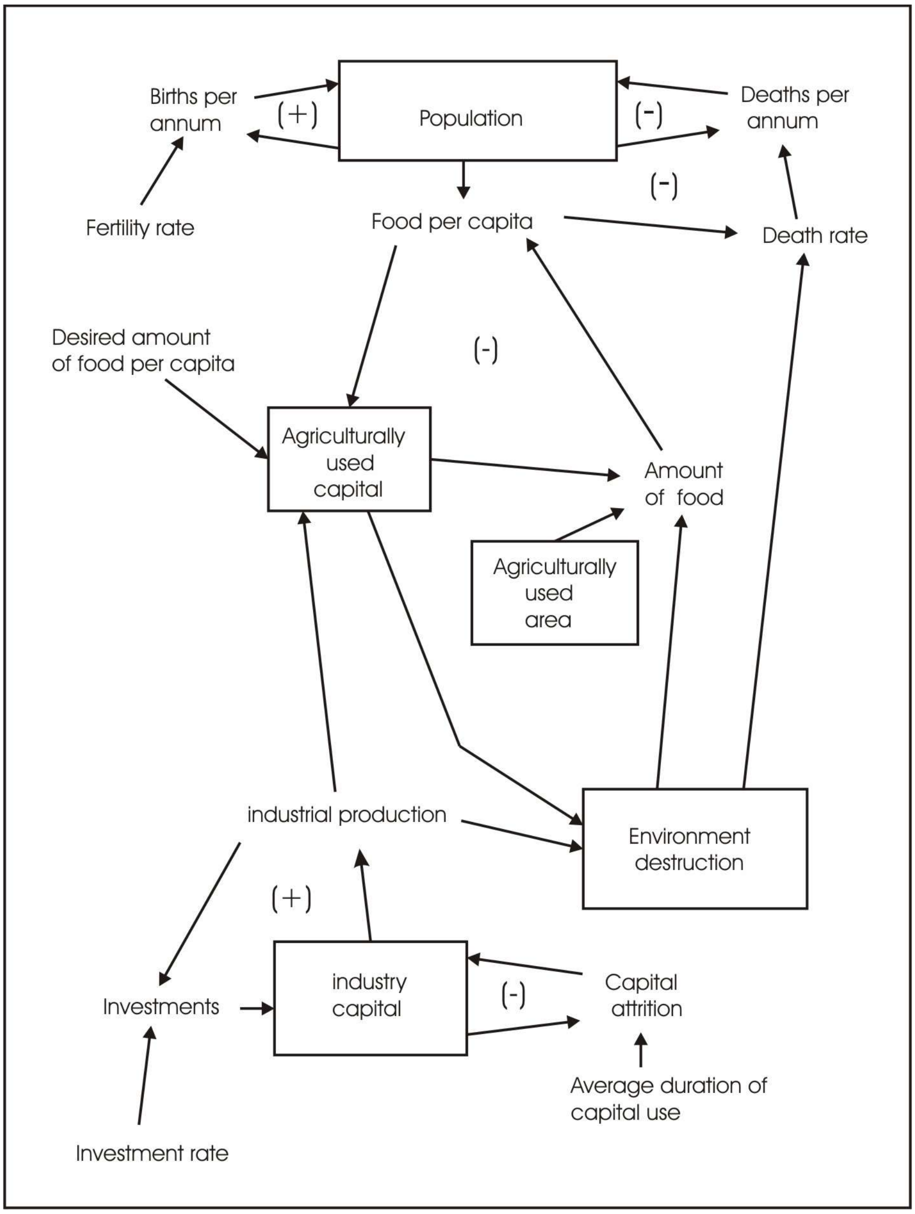


Fig. 51:
Interaction of the compartments population, capital, agriculture and environmental pollution. Example representation of an economic flow equilibrium system. From the Global Model of the Club of Rome (according to Forrester's model). (+) and (-) indicate positive and negative feedback loops.
Source: See "Notes on the figures".

compartments and 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 (see fig. 50). 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. We should distinguish between positive and negative feedback loops. With the positive feedback loop, the process is continued positive-exponentially. Developments can get out of control quickly. With the negative feedback loop, the process is continued negative-exponentially with the result that it comes to a standstill after some time (see formulae 7 and 17, sections 2.3.1.2, p.84, and 2.4.1.2, p.125).

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" (MEADOWS, MEADOWS, ZAHN and MILLING) 1972 as the basis for its assessment of the state of humanity on the earth with reference to the resources available (see also section 2.6.1.3, p.265). Among the parameters used were the population, mining, industrial and agricultural production, service industries, the quantity of known mineral resources, environmental conditions etc. A partial system is shown in fig. 51. The model has been improved in subsequent years (e.g. by VESTER and HESLER 1980; MEADOWS, MEADOWS and RANDERS 1992).

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 2.6.1.1, pp.247), and the expression "self-organisation" also appears rather vague. 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 (see also section 2.4.2.1, p.179).

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 (see sections 2.5.1.1, pp.209, and 2.5.2.2, pp.233). Many economic cycles can be interpreted as oscillations of this kind.

Predator-prey relation:

The predator-prey relationships are often quoted to demonstrate how the ecosystem tries to achieve a flow equilibrium between supply and demand. One example of such a relationship is that between the spider mite Eotetranychus as prey and the predatory mite Typhlodromus (see fig. 52). The growth of the prey (supply) gives rise to the growth of the predator (demand). In this case the order is different to that in economic systems where the supply follows the demand. The reason for this may be that it is not only the production of the systems which is affected but the very existence of the systems.

Physics in particular has an infinitely wide spectrum of examples of oscillations and waves which are not discussed in detail here. The most important point is that energy is passes from one medium to another without any one medium being extinguished.

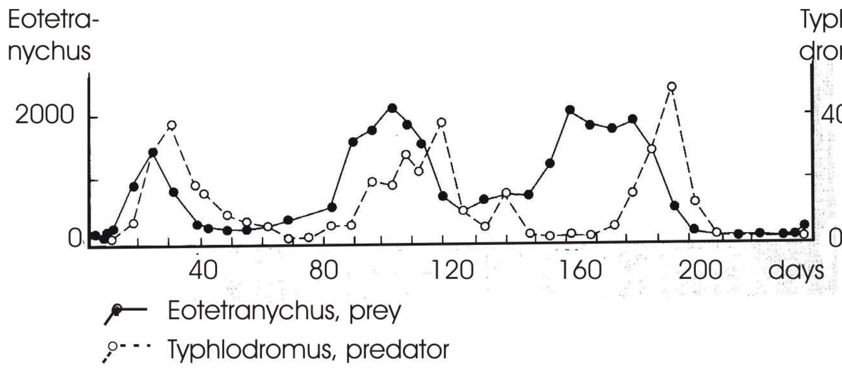


Fig. 52:
Predator-prey relationship between the spider mite Eotetranychus and the predatory mite Typhlodromus. Oscillations testify to a striving for flow equilibrium between two populations.
Source: See "Notes on the figures".

Let us return to the social and economic systems.

Business cycles:

Economic development is characterised by periodic rise and fall. Fluctuations can be seen which cover several years (see section 2.5.1.1 and fig. 53, p.210). These fluctuations are explained by the constantly changing relation of supply to demand.

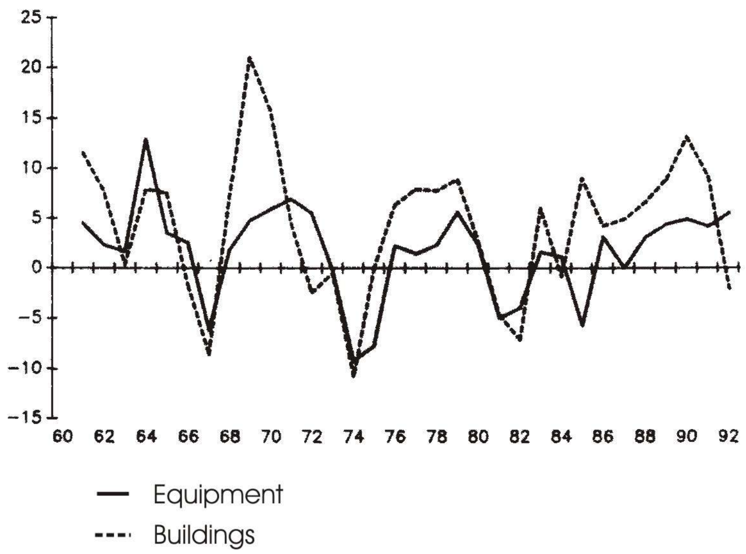


Fig. 53:
Example of a business cycle.
Several year cycle (see section 2.5.1.1, p.210). Investments in the Federal Republic of Germany (machinery and buildings). Change in relation to previous year in percent.
According to Tichy.
Source: See "Notes on the figures".

However, the Kondratief cycle, which lasts about 50 years (see fig. 54), is particularly striking. According to Schumpeter, the economy is stimulated by innovations which manifest themselves in new consumer goods, new forms of organisation, products and transport as well as the development of new

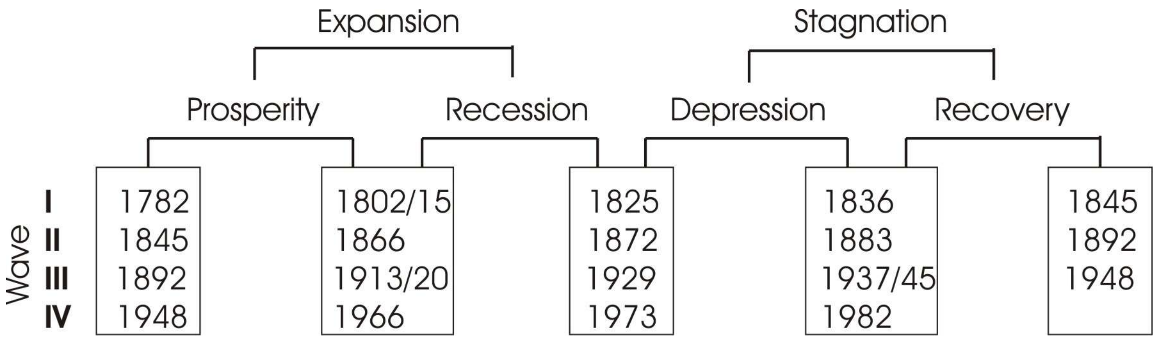


Fig. 54:
The Kondratief cycle. The 4 waves in the industrial age.
After van Duijn.
Source: See "Notes on the figures".

markets. MENSCH (1975, p. 15, pp. 76, pp. 170) also emphasises the importance of the interaction between stagnation and innovation. Stagnation, or a decline in the capacity for improvement of older technologies, suppresses the profitability of further work and capital investment in many fields of activity. This in turn concentrates the attention of science which leads to greater inventive activity. These phases are essential for the development of innovations, which are then applied industrially and new markets developed for them.

Colonisation phases:

Processes of colonisation also appear to depend on economic development, especially on the Kondratieff cycles. These also take place in phases corresponding to approximately 50-year cycles. Fig. 55 shows the phases of colonisation within Germany since the 16th century.

It is striking that the phases of colonisation are almost contemporary with the colonisation of New Mexico by the Spaniards (see section 2.6.1.2, pp.255). This indicates that the rhythm is dictated by developments in the world economy. The phases of colonisation frequently begin when the world economy loses impetus, i.e. in the phase of stagnation. Perhaps the rising unemployment in the industrial sector in these years increases the importance of the rural economy.

As a rule it may be assumed that growth in population increases the pressure to expand foodstuff production. When a certain point is reached, the process of colonisation begins. Once the basic supply of foodstuffs is secured, it gradually ebbs away. Besides the pressure of population growth as a reason for colonisation movements (which are generally encouraged by ruling elite) historical literature also cites religious and political reasons (e.g. refuge for victims of religious persecution, or hoped-for increase in revenue).

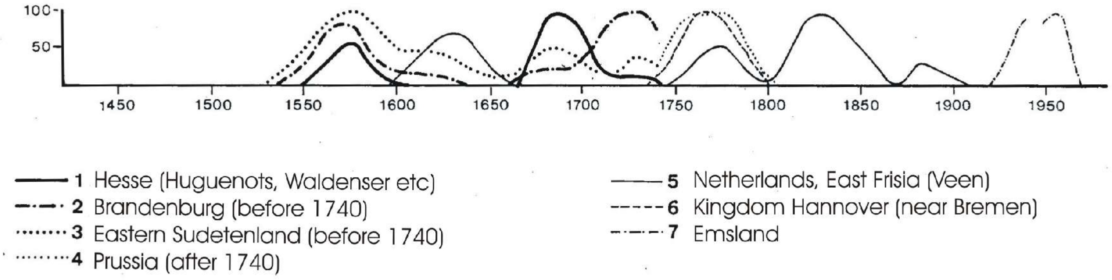


Fig. 55:
Colonisation processes in the decennial rhythm in Central Europe. See section 2.5.1.1, p.209.
Highest rate of growth in each case = 100.
(Source: see "Notes on the figures").

2.3.2.2. Horizontal processes:

Processes of spreading

Diffusion:

As described above changes of the state in social and economic reality take place in flow-equilibrium systems through the diffusion of innovations. Such a 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, and in more modern times, the spread of technical inventions such as that of the automobile (HÄGERSTRAND 1952; ROGERS 1962/83; WINDHORST 1983). The spread of artistic styles and patterns of thought has recently been described (DUMONT Weltatlas der Kunst 2004; HOLENSTEIN 2004). 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 (see section 2.4.2.1, pp.147).

One well documented example of this is the spread of covered bridges in the USA in first half of the 19th century (see fig. 56; KNIFFEN 1951). These historical structures are a striking feature of the landscape in the east of the country. The reason for the roofing of the bridges lay in the climate. At that time, bridges were made of wood and it had been noticed that the lifespan of covered bridges was around three times that of uncovered ones. They were first erected in the southern states of New England, in eastern New York State and Pennsylvania. From here, the innovation spread westwards and

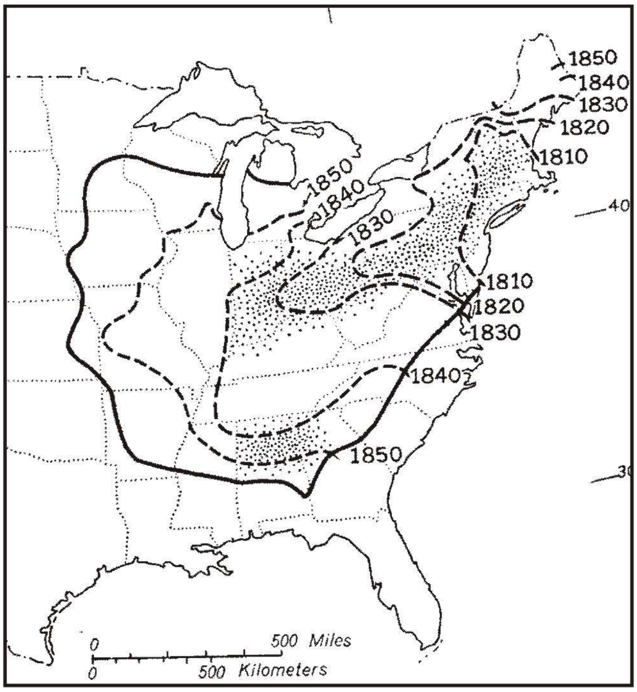


Fig. 56:
Spread of covered bridges in the east of the USA in the first half of the 19th Century. Example of a diffusion process.
Source: See "Notes on the figures".

south-westwards as the colonisation of the continent proceeded, and became less frequent around the edges of the drier plains. From the mid 19th century, covered bridges also made their appearance in California and Oregon, where they continued to spread until about 1890.

The model of Artificial Society:

The treatment of the spread of innovations and colonisation leads to the field of complexity research. Of special interest is the model of Artificial Society, which leads from the level of the flow-equilibrium system to that of the non-equilibrium system. This is a simulation model. It is true, the simulation produces spatial patterns which may look like processes of self organisation which are otherwise typical of non-equilibrium systems. However, with regard to methodology, we are dealing with a flow-equilibrium system.

This model 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.

A good example is the evolution of social networks (see fig. 57). One precondition is the structure of the "landscape". The raw material vital to the agents (under the abbreviated term "sugar") is distributed over this landscape. In two areas of this "sugarscape" it is concentrated in "mounds", at the bottom left (south west) and top right (north east). The agents move over the landscape towards these mounds, and when they have arrived there, they use up as much sugar as they can eat. Two rules are involved here (I quote literally):

1) „Agent movement rule M:
- Look out as far as vision permits in the four principal lattice directions and identify the unoccupied site(s) having the most sugar;
- If the greatest sugar value appears on multiple sites then select the nearest one;
- Move to this site;
- Collect all the sugar at this new position.
Succinctly, rule M amounts to this: From all lattice positions within one's vision, find the nearest unoccupied position of maximum sugar, go there and collect the sugar." (p. 25).
2) "Each agent again execute rule M. But now let us change the sugarscape rule to G1: Every site whose level is less than its capacity grows back at 1 unit per time period. The complete rules are then ([G1],[M])." (p. 28).

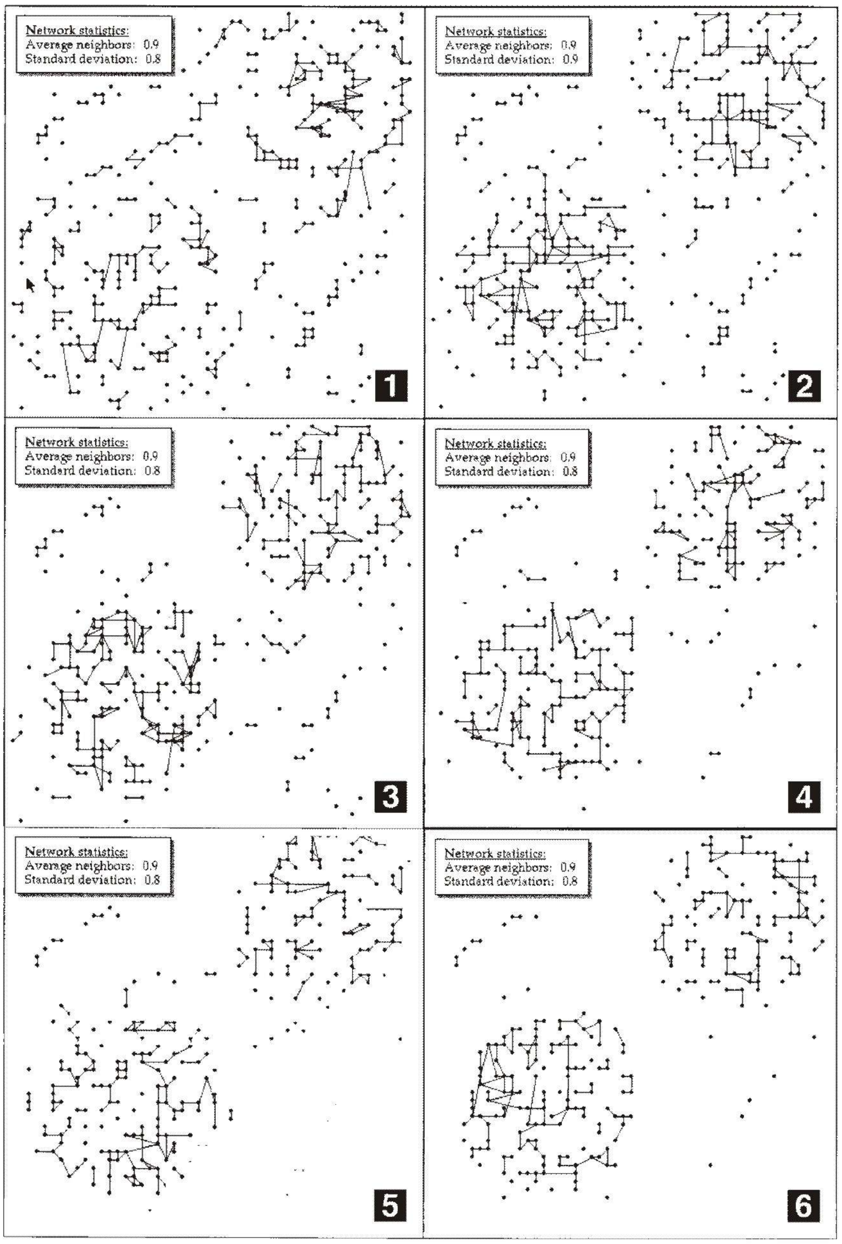


Fig. 57:
Evolution of social networks of neighbours under rules [(G1), (M)] according to the model of the Artificial Society.
Source: See "Notes on the figures".

"Social networks of neighbors...One might define the term "neighbor" in a variety of ways. Since our agents live on a rectangular lattice it is natural to use the so-called von Neumann neighborhood, defined to be the set of sites immediately to the north, south, east, and west of a particular site...... When an agent moves to a new position on the sugarscape it has from zero to four neighbors. Each agent keeps track of these neighboring agents internally until it moves again, when it replaces its old neighbors with its new neighbors. The neighbor connection network is a directed graph with agents as nodes and edges drawn to the agents who have been their neighbors; it is constructed as follows. Imagine that agents are positioned on the sugarscape and that none has moved. The first agent now executes M, moves to a new site, and *then* builds a list of its von Neumann neighbors which it maintains until its next move. The second agent moves and builds its list, and so on until all agents have moved. At this point, lines are drawn from each agent to all agents on its list. The resulting graph – a social network of neighbors – is redrawn after every cycle through the agent population. What is most interesting about such graphs, or networks, is that they change over time as agents (the nodes) move around on the sugarscape. Animation ... depicts the development of agent connection networks under rules ([G1],[M]) ...... Note that some of the neighbor graphs are simple, while others are elaborate webs containing cycles and other structures. Clearly, a rich variety arises." (p. 37 .. 40).

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 (see section 2.4.1.1, p.121). In these, production takes place, flows of energy are recognisable 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 between the specific societal constraints and the landscape, i.e. the inferior environment. This is the pre-condition for the actual emergent processes which lead to the formation of populations.

Processes of spreading in ecosystems:

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

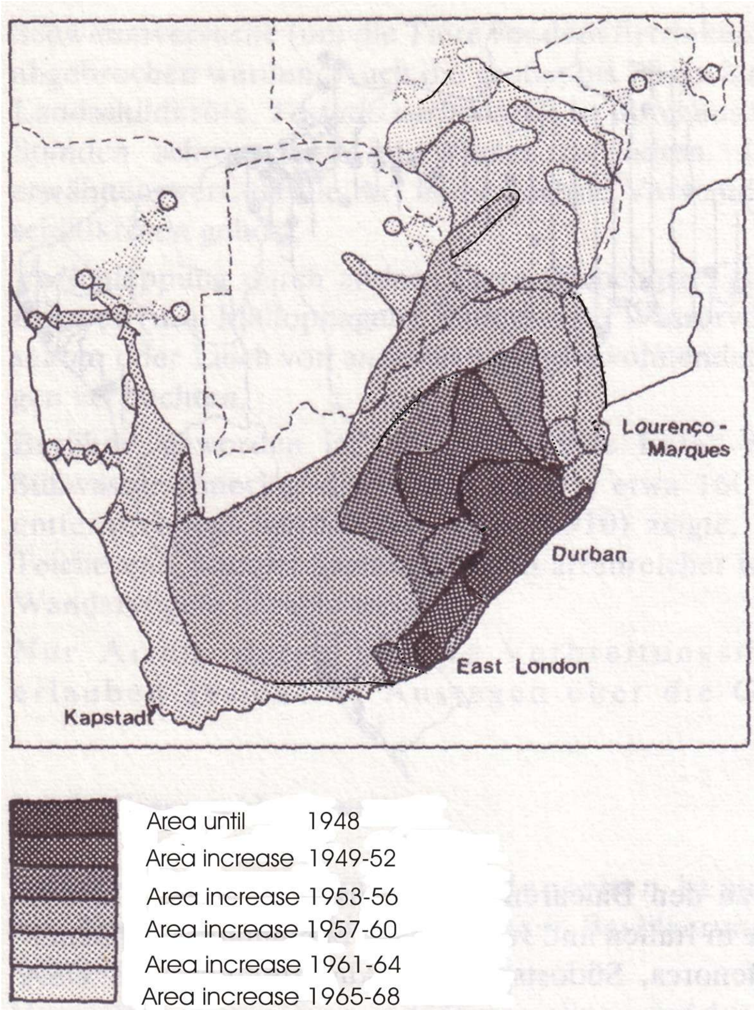


Fig. 58:
Spread of the sparrow in South Africa.
After Vierke.
Source: See "Notes on the figures".

America. These are comparable with colonisation processes. Spreading is directly observable, because it is not only information but the elements themselves which enter the environment. Changes are particularly noticeable when, due to international trading activity, new plant or animal species replace native ones. The flow equilibrium of the given ecosystem can be substantially altered by diffusion processes of this kind.

One example of this is the breeding success of the house sparrow in South Africa (see fig. 58). The birds were probably brought to the ports of Durban and East London in the 1940s and spread over all of South Africa in just two decades. Obviously they had no natural enemies.

Rotation:

Irregular rotation:

Let us return to the farm (see above). 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. I.e. the ground as inferior environment must "adopt" the stimulus to supply the demanded fruit. Through the cultivation rhythms (oscillations)

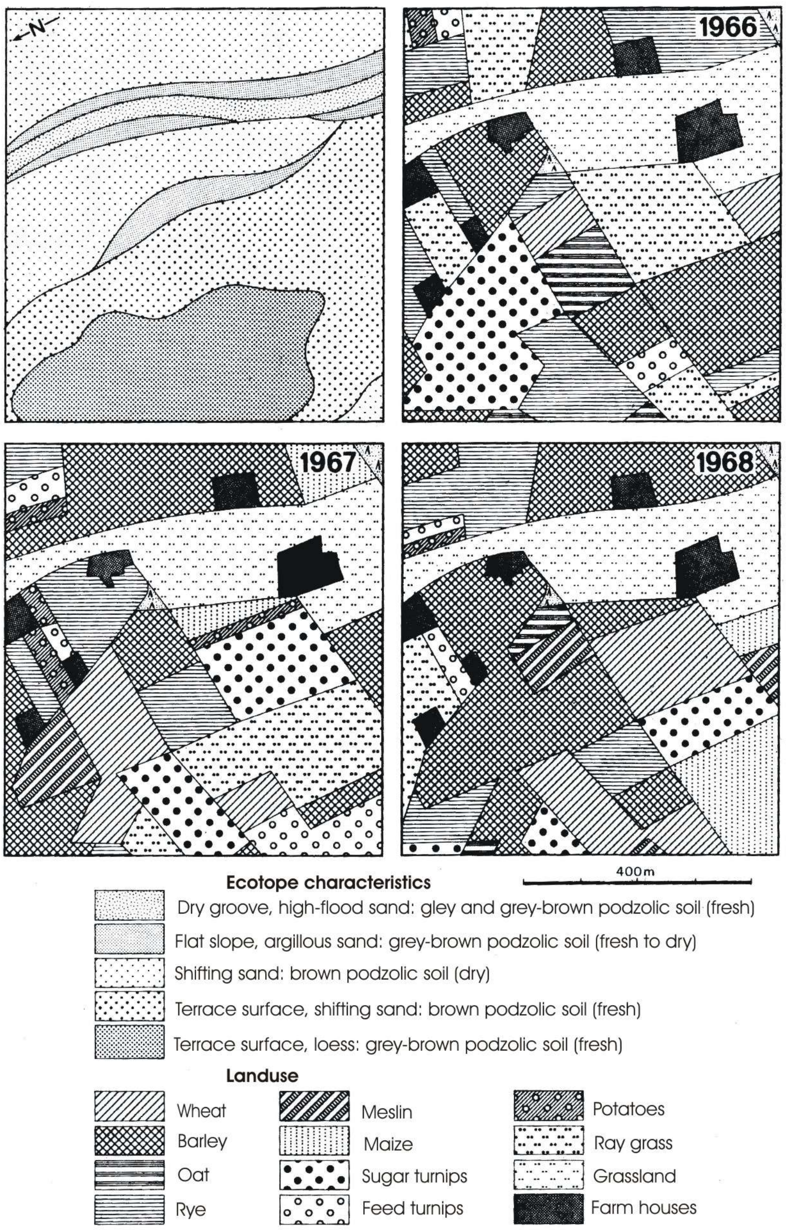


Fig. 59:
Ecotopes and agricultural utilisation (lower Rhine) 1966-68.
Example of an irregular rotation. According to Hambloch. Source: See "Notes on the figures".

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 a certain kind of "rotation" (see fig. 59; also section 2.3.1.1, pp.80). 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.

Further examples of irregular rotation are offered by the movement of centres of innovation in the course of cultural evolution in Europe (see section 2.5.2.2, pp.233).

Tangential rotation:

A tangential rotation is apparent in the long-term utilisation of the land of the Pueblo Pecos (see section 2.6.1.2, pp.254). But tendencies of this kind can also be seen in highly differentiated populations. Migrations within the precincts of a city are dictated primarily by supply and demand in accommodation. This is confirmed by an analysis of the officially reported household removals in Göttingen in 1960 (see fig. 60). In the old-town (areas 11 to 13) with its shopping district, very little new living accommodation was created in the year studied. On the contrary, much of it was sacrificed to the increasing requirement for commercial, industrial and office space. Many households living in rented accommodation in the central area moved to newly built property in the suburbs. There were therefore more removals outwards from the old town than into it. On the other hand, areas 21 and 22 at the outer edge of the town and the suburbs (areas 31-33) experienced more inward than outward movement.

In addition, certain latent tendencies are also noticeable. With the assistance of statistical analysis, it was attempted 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 (and from) the centre.

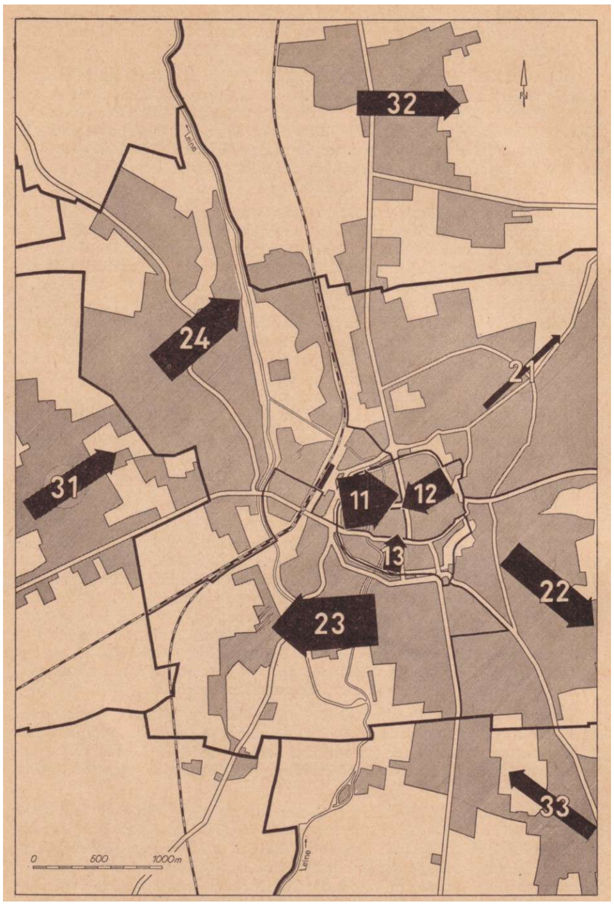


Fig. 60:
Household removals within Göttingen (and suburbs) in the year 1960. An example of a tangential rotation. Converted according to the size of the various areas. Resulting direction: the length of the determined resultants has been transposed to the width.
Source: See "Notes on the figures".

Similar trends can also be seen in the development of commuter and general road traffic. These deviations from the radial direction would seem to indicate a certain degree of tangential rotation. Unfortunately, very few studies exist on the phenomenon of rotation, although corresponding observations could be made in completely different environments and orders of grandeur.

2.3.3. Process sequences and dominant systemic dimensions

Numerical sequence:

At this 3rd level of complexity, the energy from the environment is integrated into the system. In the processes of the 1st order the vertical component comes to the fore (demand against supply). This means that the co-ordinate system is run through in clockwise direction (U variant). As a consequence of interlacement (emergence code; see section 2.2.3), the newly organised process structure appears.

The flow of information (demand) and energy supply (see fig. 61a):
[f(x)], Input: The stimulus (quantity of demand) from the superior environment enters the system.
[-f(x)], Acception: The stimulus (quantity of demand) from the system enters the inferior environment.
[-f(-x)], Redirection: Energy is absorbed from the inferior environment.
[f(-x)], Output: The energy is taken to the system and the superior environment.

That is, the energy (supply) now flows in the opposite direction from the inferior environment against the flow of information (demand) to the demanding superior environment. Then the lower part of the number table is folded behind the

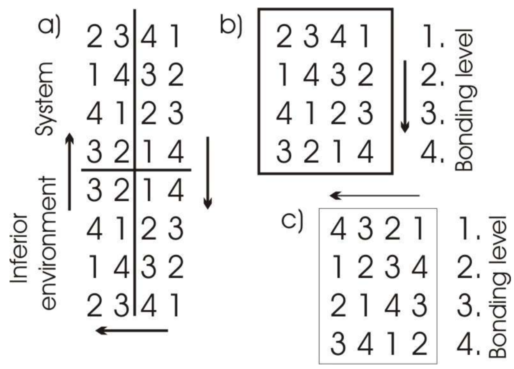


Fig. 61:
Scheme of the flow process. Numerical sequence.
a) 1st rank process (U variant, see arrows) before folding: Development from above to below and from below to above.
b) 1st rank process after folding: The lower part of the process (the involved inferior environment) is folded behind the upper part.
c) 2nd rank process (C variant), folded.
About the operations see section 2.2.3, pp.62.

upper part (see fig. 61b). 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.

The processes of the second order on the other hand proceed horizontally. In fig. 61c these processes appear (C variant). Here we refer again to the diagram showing the curve of the flow of information (formula succession) above in fig. 47, p.93.

Route diagram:

The route of the process sequence in its 3 levels is shown in fig. 62. Here, the folds are not taken into account with the result that the process sequence as a whole can be seen. The contact with the demanding and receiving (superior) environment is again located at the centre in this diagram. The flow process tends towards the right and therefore takes place in an clockwise direction (U variant).

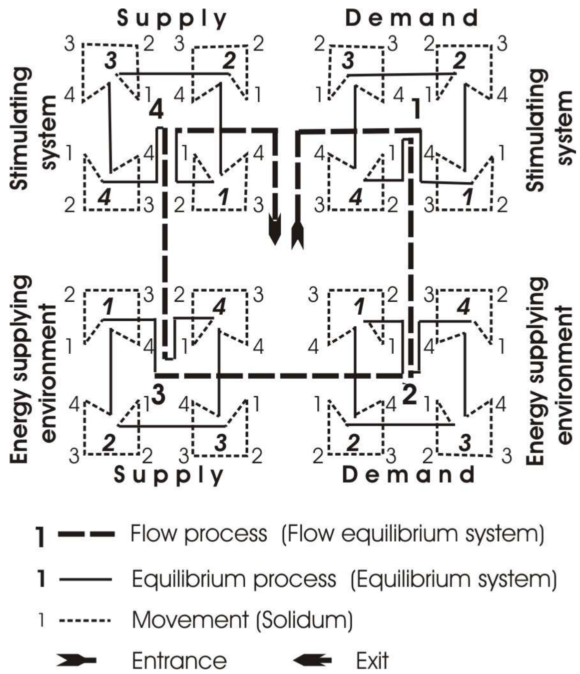


Fig. 62:
Route diagram of the flow process (flow equilibrium system), with the systems and processes of the lower levels of complexity assigned.
The first rank process is structured according to the U variant. A basic process of the next-lower level of complexity is assigned to each of the four basic-process stages of a level of complexity.
Each of the basic processes shown in the diagram represents a large number of individual basic processes.

Here, a 3-level hierarchy can already be seen. The two upper stages of the flow process (1 and 4) define the energy demanding part of the system and the two lower stages (2 and

3) the energy supplying part. The information (i.e. the demand) from the superior environment is received in the system and via (1) and (2) conducted downwards (flow of information). Here, energy from the (involved) inferior environment is made available. It is then directed via the element horizon (3) and system horizon (4) to the superior environment (energy flow). The (involved) inferior environment and system therefore face one another and regulate one another mutually.

The process is divided within itself, i.e. the processes of the first and second complexity levels are included. So, the process leads from the topmost (3rd complexity) level to the inferior equilibrium processes and from here onwards to the movements. In each case, these inferior processes must be passed through before the next stage can be begun.

The dominant systemic dimensions (see fig. 63):

Quantity: On its own, the equilibrium system is not able to differentiate itself further. At this level of complexity, additional energy is taken from the environment. The flow-equilibrium system is integrated in a higher flow of energy. This means that it receives a demand for energy from the superior environment, which it passes on to the inferior environment (flow of information). From the inferior environment, it receives the demanded energy, which it supplies to the superior demanding environment (flow of energy). How much energy can enter the system depends on the (systems of the) inferior environment and this environment is not directly subject to the control of the system. The relation between the superior environment and the system is

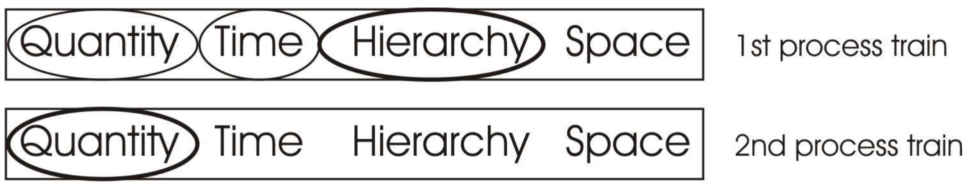


Fig. 63:
The quantity of energy appears as the dominant systemic dimension in the second process train and the hierarchy as the dominant systemic dimension in the first process train.

similar. The demand can enter the system as stimulating information from the superior environment, but the system itself is not bound by the order of the superior environment. With reference to the outwardly oriented structuring of the system (2nd process train), the quantity dimension is dominant. It is the principal vector. The activities following the other dimensions are directed by it.

Hierarchy: The flow of information and energy must be apportioned in such a way that the system is able to maintain itself. Thus, the system reacts to the demand and supply of the environments by structuring itself internally and hierarchically between system and elements (1st process train). Four bonding levels are created. In this way, all the elements are involved in the process which itself is essential for the installation of a feedback mechanism. In this way, the flows can be regulated. Whereas the quantity of the flows can be seen as being predominant for the outward structure, it is the hierarchy which dominates the internal formation of the system.

Outlook:

If a clear structure can be postulated for our reality, the question then arises as to whether everything which happens in the world fixed and pre-determined in advance down to the last detail, or is it undetermined. Or put differently, do certain laws exist which govern the course of events in nature and in thought, or do chance, arbitrariness, freedom, or whatever we choose to call it, prevail (at least up to a certain point). MAX PLANCK (1938/48, p. 4) posed this question in view of the problems unresolved in his time, such as the assumed irreconcilability of wave and particle representation in atomic physics. However, the problem "determined or undetermined" is of much wider importance, affecting, among other things, the freedom of will which is central to the subject of this book, which discusses developments in the history of thought. Planck is only one (albeit important) voice among many.

The broad spectrum of opinion on this subject cannot be outlined and discussed here, but a few remarks would seem to be appropriate in view of our results.

Processes which are pre-determined are defined in advance. The doctrine of Determinism embraces all the events taking place in the world including human action, i.e. there is a clear causal relationship between cause and effect (see section 2.1.1.1, pp.17). Processes which are not defined in advance are undetermined. Between these two extremes there are numerous positions, and the process theory in particular reveals different kinds of non-determination. The question therefore has to be put more precisely. First of all it should be said we are always dealing with situations of transition from one state to another. It is not the states themselves which are pre-determined or undetermined, but courses of events and processes. But that also means that we are also confronted with a problem of control. Fully (i.e. in every detail) controlled transitions are without doubt pre-determined. On the other hand, if no control exists, chance prevails, and the system is in danger of disintegration.

There are various ways of controlling a process sequence. The feedback indicates only one way. Flow equilibrium systems are distribution systems. However, the elements of the compartments, e.g. the textile factories in the market, can also process the energy and manufacture products. The energy is "informed", so to speak. The products can be designed in such a way that they correspond exactly to the demand. This results is an increase in effectiveness, or in other words, a saving in the amount of energy in the flow. Thus, the flow of energy can be controlled much more precisely.

This assumes a re-structuring of the flows of information and energy – a new type of system. The development of a model is a challenge which cannot be met using the methods of traditional complexity research (see Foreword). This therefore takes us to a new level of complexity.