6 Interactive, dynamic order in organisations

6.1 Introduction

6.1.1 Having discussed the concept of order and complexity in the previous chapter, we will address in this chapter the application of this concept of order to organisations. The emergence of order in the organisations is the result of an intricate interaction between entities, in organisations human beings. In this interaction different mechanisms can be distinguished. These mechanisms can be layered into a hierarchical structure, in which each layer creates the conditions for the higher level mechanism to work properly.

6.2 Order as an organisational concept

6.2.1 The concept of order can be applied to organisational structures by analysing the links between organisational entities. Different configurations yield different levels of organisational entropy (an expression of order/disorder) different N/K characteristics in Kauffman's network model.

6.2.2 Order in organisations can be seen in this way an expression of the existence of meaningful and purposeful relations between functional elements of such organisational structure. Without such relations the whole of the organisation can have no meaning or purpose. In such case the whole is identical to the sum of parts and no synergy or common purpose can exist.

6.2.3 Nonaka (1988) deals with the concept of organisational order:

> *"Order in an organisation refers to the structural and cognitive order which affects the pattern of the members of the organisational activities, namely, the pattern of resource deployment, organisational structure, systems, processes and cultures."*

He stresses that his concept of order does not only embrace physical patterns of organisational structures and systems, but also mental patterns such as visions, concepts or values.

6.2.4 We tend to look upon organisations in terms of structure and purpose, not in terms of order [i]. Somehow the very existence of the organisation implies that order is present.

6.2.5 Network analysis offers a means for bridging the gap between macro- and micro-level explanations of social structures. Research design for network analysis consists of four elements (Knoke and Kuklinski, 1983):

- Choice of sampling units, i.e. the actual network and the nodes that will be studied. The delimitation of network boundaries depends to a great extent upon a researcher's purposes;
- Form of relations, referring to a) the intensity or strength of the relation between two agents, and b) the level of joint involvement in the same activities;
- Relational content, e.g. transaction relations, communication relations, sentiment relations, authority/power relations;

- Level of data analysis. Four conceptually distinct levels of analysis can be distinguished;
  The egocentric network, or the relations of a single agent within the network (generating N units of analysis at sample size N);
- The level of dyadic relationships, i.e. formed by a pair of nodes (generating (N2-N)/2 units of analysis at sample size N);
- The level of triad relationships, i.e. formed by three nodes and their linkages (generating N/3 distinct triads at sample size N);
- The complete network, using complete information of relations among all agents.

6.2.6 Three sets of methodologies can be distinguished (Fombrun, 1982):

- Decomposing the network into its individual nodes (nodal);
- Decomposing the network into all possible pair-wise combinations of nodes (dyadic);
- Decomposing the network in an inventory of all possible triads of nodes (triadic).

6.2.7 While our research takes the dyadic approach, we do not subscribe to the strategies as proposed by Fombrun to be used within this approach, as these do not address the issues we are dealing with here.

6.2.8 Using the dyactic approach, let us consider 10 entities (in this case employees) in an organisation as a transactional network [ii] (see Figure 6-1).

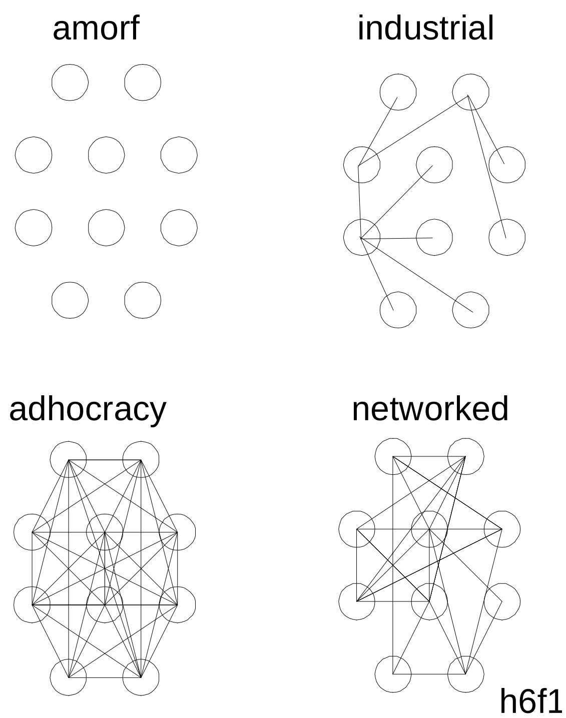

Figure 6-1: Examples of network topologies

In this figure, four possible characteristics of relations between these 10 entities are indicated. These links could be expressions of co-operation and/or communication.

6.2.9 For simplicity reasons we assume a digital situation: links exist or don't exist. All co-operation and communication below a certain threshold is supposed not to be existent, and consequently the links drawn in figure indicate strong co-operation and/or communication

6.2.10 In the left-hand example, no links exist, and as no links exist between the entities there cannot be a common objective, or meaningful identity, associated with such organisation. They are merely 10 individuals apparently arbitrarily isolated from the universe and put together on this paper. This way of arranging entities we would not call organisation, but a complete absence of any form of organisation.

6.2.11 In the second example in Figure 6-1 one of the entities is connected to most other entities. Apparently this one entity is in the centre of what the structure is intended for, and is apparently the beginning and the end of all activities undertaken by the structure. We will readily recognise the existence of hierarchy in this structure, as the central entity apparently is necessarily governing the behaviour of the other entities.

6.2.12 In the third example of Figure 6-1 all entities are connected to all other entities. In this situation where apparently all entities interact with the same intensity with all other entities, there is no structure visible. Structure which would indicate a way in which these entities relate to each other in any peculiar way, and which could provide a clue with respect to the purpose and working of the organisation. In fact if all relations are equal, then apparently all entities are universal or completely identical and if this is the case, it is difficult to see why they would need to relate to each other, other than exploiting each other's capacity in response to some outside force. The lack of own identity and purpose will make them to dead entities drifting on the external forces exercised upon the structure by the environment and hence not expressing an identity of purpose as a group.

6.2.13 In the fourth example the connectivity is substantially higher than in the hierarchical structure but substantially less than in the third example. Here a rich pattern of connections exists, suggesting some sort of meaning of relations between the various entities of the organisation. And this meaning will most likely reflect but the purpose of the organisational structure as a whole, as well as the differences in identity and capabilities of the individual entities.

6.2.14 Organisational entropy was defined as (see Chapter 5.8):

$$E = - \sum P_i * \log P_I \qquad (i = 1 \rightarrow m)$$

where P_n is the probability that a certain state will occur, in our case: the probability that a certain interaction link (above the threshold) will exist.

6.2.15 If we consider the four cases in figure A, as a maximum N*(N-1)/2 = 45 links can exist (if we take every link as a two-way interaction). Using the formula we can now calculate the organisational entropy of the various examples in Figure 6-1:

- In the first example (unconnected nodes)

  $E = -45 \times 0 * \log 0 = 0$

- In the second example (hierarchical structure), 9 links exist:

E = -9/45 ∗ log1/45 = 0.76

- In the third example (fully connected)

  E = - 1 ∗ log 1/45 = 3.8

- In the fourth example (networked structure)

  E = -20/45 ∗ log 1/45 = 1,69

6.2.16 The situation in which no links exist is in terms of order and the situation in which all links exist span the extremes, and do have no practical meaning in organisational terms. Of the other two examples, the hierarchical structure has the lowest organisational entropy, and hence represent a higher level of order than the networked structure example from Figure 6-1.

6.2.17 As stated before, interactive dynamic order the grey area between structured order and total chaos, and a network structure as shown above, in terms of organisational entropy, is neatly positioned between a structured order and a total chaos. Hence interactive dynamic ordered organisations require a connectivity which is substantially higher than the procedural hierarchical organisation, without ending into the other extreme where everything is connected to everything.

6.2.18 The same set of examples could be examined from the point of view of Kauffman's N/K topology. The hierarchical structure is sparsely connected, and therefore has a low K divided by N ratio. Such structure in Kauffman's terms provides a very clear shaped solution landscape, and relatively easily finds its global maximum in achieving solutions. The very densely connected version with a high organisational entropy level has a very high K divided by n ratio. According to Kauffman's theories, such structure is potentially capable of generating a rich variety of solutions, but its solutions landscape will look like a completely randomised surface in which it will be difficult to impossible to discriminate between the quality of solutions offered. It will therefore easily get lost in the variety of solutions it can create. The moderately connected version has a K/N ratio higher than the hierarchical structure, but considerably lower than the completely connected structure. This structure potentially is capable of generating a rich variety of solutions, while still capable of learning how to move around in the solution space, and also from this point of view such a network structure promises to have superior characteristics in meeting heterogeneity and unpredictability in demand.

6.2.19 Atlan (1979) describes that when Von Neumann tried to improve the reliability of computers (automates), he drew a parallel with living organisms. These organisms have the quality that the whole is more reliable than the sum of its parts (i.e. cells may die off, but the organism remains alive). To achieve the same with artificial organisms, he proposed a number of necessary conditions. These conditions boil down to the principle that a system should hold the middle between determinism and indeterminism. In other words, a certain level of indeterminism or 'free space' is necessary for the organism to allow it to adapt to certain levels of noise in its surroundings.

6.2.20 The first to acknowledge this principle and apply it in systems theory was Von Foerster, who formulated the concept of order from chaos. Parallel to this, the principles of order through fluctuations were formulated in thermodynamics. Their common idea was that self-organising systems do not solely thrive on order, they need a certain amount of chaos. If a system fixes itself in a certain configuration, it will no longer be adaptive. It follows that a certain amount of disorder should be present for the system to remain adaptive. In other words, the system should have a certain level of entropy, somewhere between order and chaos. In an optimally adaptive system order and variety (chaos) are in an optimal balance. Neither can be reduced without reducing the adaptability of the system.

6.2.21 Others have thought about applying measures to networked structures as well. Van Hulst and Willems (1989), for example, discriminate between measures of concentration [iii] and measures of inequality. Measures of concentration concern both a number of companies as well as size distribution. Measures of inequality measure only the distribution of size; their application is less relevant for our purpose.

6.2.22 Van Hulst and Willems [iv] mention a number of measures to characterise the concentration aspect of the networked structure. Of these five measures only the organisational entropy index and the index of Hannah and Kay meet the requirements as formulated by Hannah and Kay. The problem with the Hannah and Kay index is that for each company a decision about the weighing factor must be taken beforehand. This is not always possible. As the organisational entropy index[v] is both simple and elegant and satisfies the Hannah and Kay boundary conditions, we have selected this measure as a way of characterising the magnitude and nature of order in organisation structures. Especially where electronic means of communication[vi] make it fairly easy to measure existence and density of communication between various players, it is also a measure which can rather easily be implemented.

6.3 Archetypes of organisational structure

The topologies of order can be applied to the typology of organisations as have been described by Mintzberg, Miller and Friesen.

6.3.1 Mintzberg deducted a typology of five basic organisational configurations: the simple structure, the machine bureaucracy, the professional bureaucracy, the divisionalized form and the ad-hocracy (Mintzberg, 1983).

6.3.2 Miller and Friesen (1984) treat organisations as complex entities whose elements of structure, strategy and environment have a natural tendency to coalesce into quantum states or 'configurations'. These configurations reflect the integral interdependencies among their elements (as opposed to the contingency view). It should be noted that a relatively small number of these configurations seem to encompass a large part of the population of organisations. It is important that to a large extent the quantum view is based on empirical work.

6.3.3 On the other hand typologies like Mintzberg's are exclusively theoretical concepts. According to Miller and Friesen:

"[...] typologists impose order upon the world of organisations."

6.3.4 In their empirical research Miller and Friesen (1984) simplify the Mintzberg typology into the triad: simple firms, planning firms and organic firms. In simple firms (comparable with Mintzberg's simple structure) power is highly centralised in the hands of one or two persons; the orientation of the firm is tied to one central agent, as in the example 2 of Figure 6-1. Generally there is little planning, time horizons are short, and focus is on operating matters rather than visionary master plans. There is little functional specialisation. The environment is simple, yet it can be very dynamic.

6.3.5 The planning firm resembles Mintzberg's machine bureaucracy. It is characterised by extensive functional specialisation, bureaucratic control and elaborate planning and prediction systems. Decision-making is dominated by a powerful central group of managers and technocrats (a large technostructure exists). The emphasis is on a smooth, efficient and regular functioning, like a machine. The environment is typically simple and stable, which allows the firm to maintain its mechanical operating mode. The firm buffers itself against the environment by abundant storage of slack resources. In dynamic and complex environments the sophisticated control, planning and prediction systems cannot function. Typically the firm cannot respond to such environments. In terms of topology, such firms look like an expanded version of the 2nd example of Figure 6-1.

6.3.6 The organic firm, much like Mintzberg's ad-hocracy, manages to adapt to heterogeneous and unpredictable markets. It does so by adopting an organic structure, delegating power and authority to the operational level, striving for high differentiation (individuals and departments with different abilities must be able to deal with different environmental requirements), maintaining an open relation with the environment to detect important challenges and opportunities, and aiming at an extensive and open internal communication

6.3.7 In the table below we confront the three forms of organisational order as defined in par. 6.2 with the most important criteria of Mintzberg's typology.

Key dimensions in Mintzberg's typology	Industrial order	Networked order	Chaos
Key co-ordinating mechanism	Standardisation of work	Interactive behaviour	Interactive behaviour
Key part of the organisation / power	Strategic apex/ technostructure	Operating core	Operating core
Specialisation	Much horizontal and vertical task specialisation	Horizontal and vertical specialisation	Much horizontal specialisation
Formalisation: bureaucratic/ organic	Much formalisation/ bureaucratic	Little formalisation/ organic	Little formalisation/ organic
Planning and control	Much planning and control	Process goals, connectivity mgt., equivalence setting	Limited planning and control
Liaison devices	Few liaison devices	Varies according to environmental complexity	Many liaison devices
Decentralisation/ grouping	Functional hierarchy	Hierarchy of processes	Extensive decentralisation/ ad hoc grouping
Similarities to Mintzberg's/ Miller and Friesen's typology	Machine bureaucracy/ planning firm	none	Adhocracy/ Organic firm

6.3.8 The principle of order in the simple firm and the planning firm is much like the structural order described before. It is not the interaction between the entities (comprising the organisation) that governs their behaviour, but rather the instructions as designed by the firm's technostructure or strategic apex. In the concept of the planning firm, the principles of industrial order can be readily spotted in design principles Mintzberg mentions. In the simple firm, much the same principles apply, albeit at a lower level of sophistication; e.g. elaborate specialisation is still absent because there are relatively few people to perform a large variety of company tasks; relationships are less formalised because of the smaller workgroup. What is done in the planning firm by the technostructure in terms of planning and control, standardisation, etc., is done in the simple firm by the strategic apex in terms of direct supervision. To outside observers this order is quite evident, it can be easily understood and related to.

6.3.9 Relating the concept of the organic firm (Mintzberg's adhocracy) to our concept of networked order or to the concept of chaos is more difficult, however. Whereas the key co-ordinating mechanisms (i.e. mutual adjustment of interaction) and the key part of the organisation (i.e. the operating core) are the same, there are some subtle differences regarding the design principles of 'liaison devices' and 'grouping'. In the concept of networked order, the presence of liaisons between entities will vary according to the complexity of the environment. With reference to the adhocracy, Mintzberg talks of 'many liaison devices', which would be closer to the concept of chaos. Concerning 'grouping', networked order relates to grouping in a hierarchy of processes. Chaos would imply ad hoc grouping without any underlying principle. With reference to the adhocracy, Mintzberg's talks of functional or market grouping, which resembles neither networked order nor chaos.

6.3.10 As the differences between the various concepts are not entirely evident, the question emerges whether the behaviour of the entities in relation to each other is orderly, in the sense that the arrangement is regular (methodical), or whether it is more ‘erratic’, as Mintzberg's ad-hocracy description suggest. The determining factor is whether a structure of connections underlies apparent chaotic behaviour (hence a moderately connected structure), or whether in fact this is an expression of our densely connected structure (Figure 6-1, example 4). Whereas one has purpose and identity, required in the interaction with other networked systems to exploit the value of heterogeneity, the other drifts passively on external forces, and will get lost under conditions of unpredictable heterogeneity. Its behaviour will not be different the Brownian movements caused by external forces. It is therefor that highly decentralised companies often fail to create a meaningful coherence between their entities. These entities collide, thereby generating friction and heat, instead of showing concentrated and meaningful collective behaviour. The type of order, which comes to mind, is sooner the absence of order (chaos) than a hidden structure of meaningful interaction.

6.3.11 Both craft-type companies, as well as highly decentralised companies, often fail to create a meaningful coherence between their entities. These entities collide, thereby generating friction and heat, instead of showing concentrated and meaningful collective behaviour. The type of order which comes to mind, is sooner the absence of order (chaos) than a hidden structure of meaningful interaction.

6.3.12 Coherent, orderly and meaningful collective behaviour of collections of economic entities is sooner to be observed in successful economic networks as described in Porter's 'The Competitive Advantage of Nations' (1990). It is here that the natural absence of central command and control has forced the emergence of interactive order.

6.3.13 The existence of order in corporate structures is the base for synergy in business. In fact, in companies the mere existence of synergy is an expression of order. By linking separate corporate functions it expresses the ability to add more value. It is as if value were created out of nothing, but in fact it stems from the connection between the various entities, in this case functional units within the company:

- In the case of purchasing synergy, the creation of such value is based on the ability to exercise buying power, or to exploit economies of scale at the supplier's end. The synergy within the supply chain is based upon the exploitation of economies of scale in a process in which a relative cost advantage can be achieved through re-use of material and non-material assets;
- Cross-selling synergy is based on the ability to exploit client or market access over a multitude of businesses, by bringing commercial functions together;
- Finally, know-how synergy is based on communicating leverage information and know-how from one part of the company to another.

6.4 The hierarchy of networked co-operation mechanisms

The emergence of networked co-operation can be seen as a hierarchy of layers, each layer representing a necessary mechanism of interaction, required as a precondition for higher layers.

6.4.1 In the atomic perspectives typically assumed by economics and psychology[vii], individual agents are depicted as making choices and acting without regard to the behaviour of other agents. In contrast, network analysis incorporates two significant assumptions about social behaviour:

- Any agent typically participates in a social system involving many others;
- A social system contains various levels of structure, or 'regularities in the patterns of relations among concrete entities'.

6.4.2 Social behaviour can be treated from both the perspective of attributes (i.e. characteristics) of social entities and from the perspective of relations between social entities. Relational measures capture emergent properties of social systems that cannot be measured by simply aggregating the attributes of the individual agents. Relations are the building blocks of network analysis. A network is generally defined as a specific type of relation linking a defined set of entities (or nodes). The configuration of present and absent relations among network agents reveals the specific structure of the network.

6.4.3 In this section we will explore the various mechanisms which give rise to the emergence of meaningful relations between the entities of a network structure. These mechanisms can be seen as a layered structure, almost as a hierarchy of mechanisms and is a pyramid with the various layers on top of each other (see Figure 6-2).

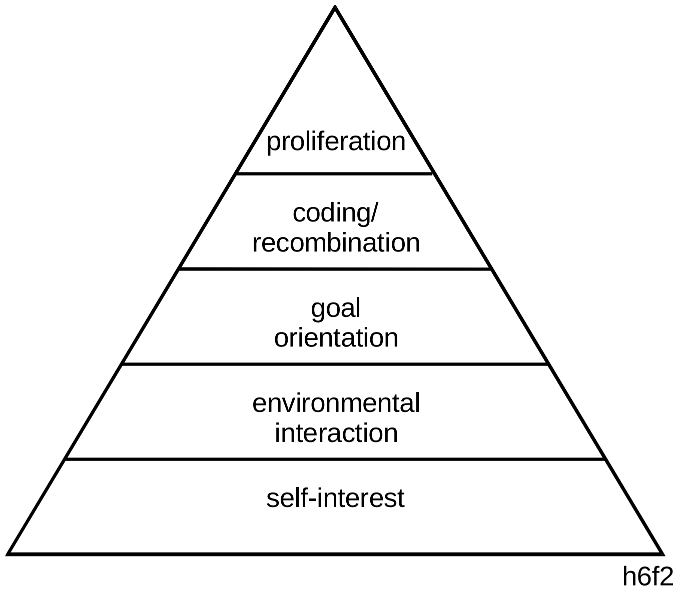

Figure 6-2: Hierarchy of networked order mechanisms

6.4.4 At the bottom of this hierarchy are the mechanisms required to convert self-interest of entities into some form of networked co-operation. As this layer of mechanisms gives rise to at least some form of networked behaviour, the next layer of mechanisms create interaction with the environment in order to develop knowledge about how to pursue the goals and ambitions of the networked structure in its relevant environment. The third layer of mechanisms enable these experiences to be discriminated with respect to the contribution they make in a desired direction, and the ability to decompose such experience in meaningful chunks of knowledge which can be recombined and transferred. These coding and recombination mechanisms form the next layer in the hierarchy. The top of the hierarchy is formed by the mechanisms, which enable effective proliferation of knowledge to other parts and other network structures within the same meta-structure. It is truly a hierarchy, in the sense that higher-up mechanisms do simply not work as long as the lower level mechanisms are not working adequately.

6.5 Self interest in multiple bilateral relations

Agents will only co-operate on the basis of perceived self-interest. This necessarily implies the agents in networks cannot be identical.

6.5.1 Both common and adverse interests, whether between employees, between employees and managers or between managers and clients, will determine each relationship between two agents. Adverse interests are especially evident when the agents belong to separate sub-groups. Also however, adverse interests will always occur between people of the same group, or people who belong to groups which are part of the same sub-system. Without such adverse interests there would be no raison d'être for the respective groups. On an individual basis it is unthinkable that people will always have the same interests.

6.5.2 On the other hand, if only adverse interests exist or if the common interest is smaller than the adverse interest, coherent networks will not emerge. The network will become like melting ice; it will display random movement without any coherence and will be driven by the collision between the particles.

6.5.3 Each networked structure consists of a multitude of bilateral relationships between individual entities. This does not necessarily mean that network behaviour can be reduced to bilateral relations. However, if we want to understand coherent behaviour in networks, we will first have to understand the bilateral interaction at the entity level. Within these bilateral relations both attracting and opposing forces are active. It is only under certain conditions that the attracting forces become larger than the opposing forces and co-operative interaction will take place[viii]. We will not naively assume that agents' interests are essentially equal and automatically lead to co-operation. Nor will we assume that agents' interests will be only opposed and so inhibit interaction.

6.5.4 Agents are not limited to communicating information. They can also generate complementary value(s), which implies automatically that agents cannot be identical. They have a relation based on the exchange of value, as was described at the level of the stakeholders in terms of the coalition of interests at the base of the company (see Chapter 2.2).

6.5.5 In their discussion of determinism vs. voluntarism in complex organisations, Thiétart and Forgues (1997) support this view in quoting Thompson (1967):

> *"The complex organisation is a set of interdependent parts which together make up a whole, in that each contributes something and receives something from the whole."*

They also discuss the ideas of Kahnemann and Tversky (1984), Tversky and Kahnemann, Lichtenstein (1981, 1988) and Slovic (1971) and Tversky, Slovic and Kahnemann (1990), stating that agents have different frames of reference, different value systems and preferences. Actors sometimes have contradictory objectives and stakes. As a result, these authors state, only a complex relationship can exist between the different agents of the organisation:

> *"We are dealing with non-linear dynamic systems, characterised by interactivity, time dependence and sometimes tight coupling."*

6.5.6 If two agents interact with each other, the utility exchanged must be different[ix]. For example, if I have apples and you have apples too, there is no point in exchanging them. This is not just true at the individuals level, but also at higher levels of aggregation.

6.5.7 In discussing inter-organisational networks, Thorelli (1986) addresses the subject of overlap and differences between organisations in the network.

> *"The domain of any organisation may be defined in terms of five dimensions: the product (or service) offered to the environment, the clientele served, the functions performed (=mode of operating), its territory, and the factor time. For a network to exist there must be at least a partial overlap in domain (e.g. synchronisation in terms of time). Should there be total overlap we have a case of 'head-on' competition [...]."*

6.5.8 Thorelli argues that in this case, networking remain possible, albeit in the form of cartel-type arrangements, i.e. aimed at avoidance of competition, but not generating any complementary value. He continues:

> *"Division of labour and synergistic network opportunities are likely to be more prevalent and more effectively implemented when the overlap in dimensions is much less than complete."*

6.6 Exchange of values

The emergence of order requires an exchange of utility between the agents to take place. For the whole of the networked structure this exchange should be a non-zero-game.

6.6.1 Such interaction will only emerge if the network agents can exchange values in a meaningful way. If no central power is available, no order can be forced upon the network. Therefore the order emerges out of bilateral interaction between the agents[x]. For such interaction to take place, exchanges will have to be made: no interaction without exchange. Here we are only concerned with meaningful interaction between agents. Incidentally, it is possible that non-meaningful interaction will take place (e.g. as a result of trial and error), but order demands meaning. By this we mean that reward has to counterbalance the effort put into the interaction.

6.6.2 According to the social exchange theory (Roloff, 1981)[xi] exchange can be defined as follows:

> *"The voluntary transference of some object or activity from one person to another in return for other objects or activities. The central idea is that agents are prepared to enter into exchange relations when their own self-interest will be served by the exchange* [xii]*."*

6.6.3 Exchange objects represent utilities. Value is a subjective notion, determined by expected utility for the agent. As will be reasoned in par. 6.7, agents only effectuate exchange when the values received (the rewards) will more than offset the values offered (the costs), i.e. when the profits or results of the exchange will be positive.

6.6.4 Internal exchange is governed by what Achrol (1997) calls the internal market network. This concerns a firm, organised in internal enterprise units that operate as independent profit centres. They buy from, sell to or invest in other internal and external units as best serves their needs; they do so on trades that are determined by the market, but subject to firm policy. This means that hierarchic relationships are replaced with direct exchanges among organisational units, mediated by some type of market-like processes.

6.6.5 The binding in organisations thus resides in the common interest, equally on the level of the individuals as various sub-systems (the shareholders/owners, the employees and the clients) and on organisational level between the sub-systems and the system as a whole. Common interest can only be sufficiently large for everybody when the interests of one group are not fulfilled at the expense of another group or of the system as a whole. Achieving a sufficiently large common interest therefore presupposes a symbiotic strategy rather than an exchange strategy; in other words, it presupposes strategy as a non-zero-sum game as opposed to a zero-sum game.

6.6.6 A symbiotic strategy is characterised by a positive link between the interests of the system as a whole and the various sub-systems and individuals. It is a game in which value is not just distributed or redistributed; it is a game that creates additional value. Interactive, self-regulating forces which are necessary to create effective networks, can therefore only exist if the ultimate value will be larger for all concerned: shareholders, clients and employees. Interactive self-regulation cannot emerge in a pure exchange strategy in which total value remains constant.

6.7 Outrageousness, challenge and stretch

Order will only emerge and networked order will only evolve if the collection of agents is subjected to goals that cannot be achieved through current work practices and current levels of co-operation. Such goals can be considered outrageous within the context of current experience and imply stretch. Formulated in another way: evolution arises out of limitations.

6.7.1 The presence of a larger total value is in itself not sufficient as a boundary condition for effective self-organisation. Co-operation, based on ever-present self-interest, will require energy. This means that the individual agent will prefer to achieve his goal in isolation. He will only put energy into co-operation if that is the only way or an easier way to achieve his goal. In other words, self-regulating interaction does not only require the desire of individual agents to achieve the same goal, it also requires goals that cannot be achieved in isolation. This is why the goal must be external to the agents (not to be achieved within the existing structure), to sustain the coherence in development of a company. It must also be rooted in the strategic ambition of the company. Otherwise, the attracting force of co-operation will prove to be insufficient to initiate network coherence.

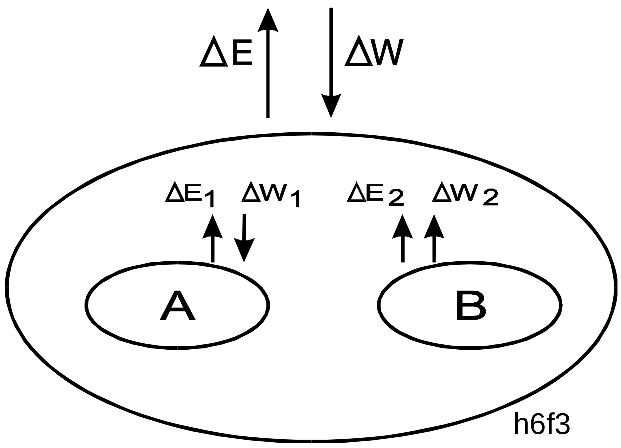

Figure 6-3: Energy and rewards at an individual level

6.7.2 This is schematically indicated in Figure 6-3. If achieving a common goal has to be made attractive, the sum of rewards (ΔW) will have to be larger than the energy required (ΔE) to achieve this goal.

6.7.3 Embarking on new co-operation will always cost energy, which will have to be invested. This energy could either be a mental or practical parting with skills or possessions, or effort put into forming new relations (e.g. marketing investments). Agents will only act if the utility output they personally perceive (which is not only financial) will sufficiently compensate for the energy put in.

6.7.4 Therefore, if agents are to be led towards meaningful co-operation, the goals must necessarily exceed the levels that can currently be attained. If with the existing rule-set the network can satisfy all agents, the motivation to become ever better has gone. Only if the network is confronted with situations in which existing rule-sets are inadequate, is it driven to improve.

6.7.5 Adequate, in these terms, is a situation in which the network is able to satisfy the interests of all stakeholders. Consequently, networks need to face up to ambitions which cannot be achieved within the current rule-set. For example, by not trading-off process performance against process efficiency, but by improving the combination of both, the network will be encouraged to study and understand new rules. This is the basis for creating evolution aimed at sustained growth of value and utility for all stakeholders. This implies recognition of the self-interest of the agents. Otherwise, improvement would cease as soon as the interest of power would be satisfied.

6.7.6 In other words: the meaning of networked coherence is to realise ambitions which previously were not possible. Such an exchange will require efforts (energy), and agents will only join such a co-operation if it will result in added value, seen from their value perception. The only way to catalyse networked co-operation is to expose the networked structure to outrageous[xiii] goals. "Because it is impossible, it's a goal". In management behaviour this is quite contrary to the convention in most companies. And it explains why self-organisation in crisis is a lot easier than in normal times.

6.7.7 Agents will only continue co-operating if enough added value materialises to off-set the energy investment. Whereas the previous argument concerns the creation of value, this addresses the distribution of value. It is not only true for the total, it is also valid at the level of the separate players in a network. Just as for agent A, the reward for agent B needs to be larger than the sacrifice. These boundary conditions are mathematically formulated in Figure 6-4.

$$\text{(I)} \quad \frac{\Delta W}{\Delta E} > 1$$

$$\text{(II)} \quad \frac{\Delta W_1 + \Delta W_2}{\Delta E_1 + \Delta E_2} < \frac{\Delta W}{\Delta E} \longrightarrow \text{ or } \begin{array}{l} \Delta E < E_1 + E_2 \\ \Delta W > W_1 + W_2 \end{array}$$

(synergy)

$$\text{(III)} \quad \frac{\Delta W_1}{\Delta E_1} > 1 \cap \frac{\Delta W_2}{\Delta E_2} > 1$$

h6f4

Figure 6-4: Boundary conditions for co-operative behaviour

6.7.8 Nonaka (1988) states that complex systems self-organise towards a definite order. Once attained, this order is continually challenged by new information, which leads to fluctuations of elements in the system. Sources of this new information are:

- Market, technology and inter-company network dynamics;
- Built-in organisational structures, systems and processes.

6.7.9 Different kinds of information, which arise in this manner, compete with and complement each other and are sometimes denied. The system is not swayed completely with coincidental fluctuations. Rather, it amplifies certain fluctuations selectively, thereby forming a new structural and cognitive order. Thus, according to Nonaka, information of even higher levels is created, which leads to a change of cognitive and behavioural patterns in the organisation. In this way, one form of order is substituted by another through the creation of information. This process of dissolution and creation of order shapes the self-renewal of the organisation.

6.7.10 Discrepancies arise between the newly created strategic vision and the current situation. Nonaka:

> *"A challenging but equivocal vision encourages people to search or new meanings in which to integrate various interpretations and contradictions."*

6.7.11 In his article on evolutionary organisational change Duening (1997) supports this idea:

> *"In the end it is simply not possible to avoid the selection pressures of the organisation's competitive environment. Managers who realise this will allow organisational mutations to bubble to the surface."*

By keeping workers focused on the long-tern goals and allowing behavioural mutations to play out, managers are likely to find many mutations that will lead to new competitive advantages, Duening says. Managers can coach this process by selectively responding to those mutations, encouraging those that are adaptive and discouraging those that are not.

6.8 Tacit knowledge and rule systems

Agents in networked systems build know-how on how to interact with other agents in a way that best serves their self-interest. This know-how can be described in the form of (though is not necessarily equal to) rules linking events to actions (IF/THEN rules). Sets of such rules can considered to be (part of) the tacit knowledge in the organisation.

6.8.1 How do agents know how to relate to each other in a way that is mutually successful for the whole as well as for the individual agent? In order to create a stable and coherent self-organised structure, this can clearly not be done by continuous trial and error. Some sort of memory at the level of the agents is hence required in order to remember how to successfully relate to other agents in the environment. In this way the agents individually, as well as the total networked system, builds up information and know-how with respect to the question how to deal with the environment.

6.8.2 This makes us touch on the concept of knowledge. Nonaka (1988; 1994) discusses the concepts of explicit and tacit knowledge. Explicit or codified knowledge refers to knowledge that is transmittable in formal, systematic language. On the other hand, tacit knowledge has a personal quality, which makes it hard to formalise and communicate. Tacit knowledge is deeply rooted in action, commitment, and involvement in a specific context.

6.8.3 It is intuitive knowledge that cannot be completely expressed in words or writing (syntax). This kind of knowledge is particularly characterised by an internalised understanding gained from previous actions, i.e. experience-based. Nonaka argues that this 'tacit knowledge' often becomes the basis for information creation. For this information to be actualised beyond the levels of individuals and divisions, a dynamic co-operation throughout the whole organisation should take place (Nonaka refers here to a rugby team). He further states that in the creation of information, the organisation members should compete with each other. This statement is, however, not motivated.

6.8.4 Tacit knowledge is present in an organisation but cannot be easily explained, although there have been experiments with building expert systems, in an effort to capture it. Expert systems [xiv] are built by asking questions like: "If this happens, what do you do then?" The intention is not to try and understand why something is the way it is; there is no rationale behind it. For example, if in medicine symptoms are x,y,z then probably being ill is q. This is contrary to absolute knowledge, which to a certain extent works conversely. For instance, if ill is q at present, it should lead to symptoms x,y and z. Tacit knowledge is knowledge without scientific foundation; it is the knowledge of experience.

6.8.5 Any agent will only be receptive to a limited number of stimuli from its environment. Either because of the nature of his receptors (senses) or because of inhibitions to observe certain external events (See 6.8: Stacey). In the same way there will be only a limited number of actions it can undertake, to influence the surrounding world. An agent can thus be seen as an input/output device, interpreting inputs, and converting these to output based on success experienced in the past. Seen in this way tacit knowledge is very close to a set of IF-THEN building blocks.

6.8.6 Holland (1995) argues that adaptability of agents to evolutionary processes is determined by rules [xv]. To explain their behaviour, simple IF-THEN rules can be used. Rules are discovered by means of trial-and-error processes. Holland:

> *"This procedure may work on occasion, but is does not make much use of experience."*

6.8.7 In a network large numbers of rules are simultaneously active, comparable to 'parallel processing'. To illustrate the way this works, Holland gives a metaphoric example of an office which has a bulletin board:

> *"The workers in the office are assigned desks, each of which has responsibility for responding to certain kind of memos on the bulletin board. And, of course, the output of each desk is more memos. At the beginning of the day, workers take down memos, they process them throughout the day, and at the end of the day they post the memos that have resulted from their efforts. In addition, some memos come in from outside the office, and some memos go from the office to the outside. [...] many activities go on simultaneously, only some of them visible from the outside."*

6.8.8 The basic mechanism that underlies the next two examples is that the most effective rules for group behaviour were discovered by parallel experimentation. The players proved to be able to distil successes and failures out of a relatively noisy environment, where no player had detailed information on the behaviour of the other players. Yet in both cases, they were able, by trial and error, to work out the input/output relationship very quickly; in other words, they found the most effective 'THEN' to follow the 'IF's'.

Example

Computer simulated aeroplane

In Kelly's book ‘Out of Control’ (1994) an experiment is described in which several thousand people are collectively in control of a computer-simulated aeroplane. These people are put together as an audience into a hall and each individual person receives a card with a green front and a red back. A camera surveys the hall, reads the red/green information from the cards and conveys this information through a projector onto a large screen, which can be seen by everyone in the hall. As a first exercise, the game leader asks the audience to create a circle on the projector screen. After a bit of trial and error, the audience succeeds, much in the same way as spectators in large stadiums can create pictures through the use of flags. In Kelly's experiment however, no detailed instructions are given to individuals as to how they should behave. They must find that out for themselves. The experiment continues by asking the group to carry out more complex actions, such as putting figures in the circle. After this learning stage, the computer-simulated aeroplane is started; half of the audience will control the direction, the other half will control the altitude. In the end, the audience is able to make a real loop with the simulated aeroplane. The experiment is interesting, because it indicates that provided there is a common ambition, a clear goal, and access to real-time results, large groups can behave almost like an individual and display coherent, meaningful behaviour. They learn to act as a single being, as if their brains were connected to become one super-individual.

Simulated racing car

In our own offices we created a similar experiment, though in a much easier set-up: instead of a flight-simulator, we used a simulated racing car on a track, from a commercial computer game. However, instead of a single steering wheel, we mounted ten steering wheels in sequence. With each wheel the direction in which the car would go, could be individually controlled. Ten people were placed behind these steering wheels and were asked to drive the car. Amazingly quickly, they were able to drive the car collectively, displaying remarkably coherent control behaviour. They were quite able to compensate for different steering abilities within the group. One of the most interesting events occurred when someone deliberately started steering in another direction than the rest of the group. Aggressive reactions followed and the group very rapidly compensated this individual's deviant behaviour.

6.8.9 Three basic forms of IF-THEN rules exist:

- In an industrial structure rules are generally instruction rules, forced upon the agents;
- In competitive structures the rules are generally antagonistic rules, which work against each other. If one agent wins, the other loses (zero-sum games);
- Self-organisation requires co-operative rules.

6.8.10 Network order presupposes a binding force; therefore co-operative rules are required. They are interactive, unlike the rules in an industrial structure. Many examples of complex network structures appear to be based on co-operative rules. Rules to negotiate a roundabout are co-operational rules, but so are the rules which govern ants in building a nest (see Chapter 5.7.11).

6.8.11 One of the most successful co-operational rules is TIT FOR TAT the rule, which proved to be superior in Axelrod's sequential [xvi] prisoner's dilemmas when it came to overcoming hostility. As a co-operative rule it can also be expressed in IF-THEN terms: if you prove to be trustworthy during our first encounter, I will trust you next time; if not, I will distrust you and will not co-operate.

6.8.12 The evolution of IF-THEN rules is a continuous trial-and-error process, of which the rate of performance improvement is greatly influenced by the ability to share and re-combine successful rule-(sub) sets throughout the network by parallel processing, coding, recombination and proliferation. This topic will be addressed in par. 6.10 and 6.11.

6.9 Mental models

The set of IF/THEN rules represents mental models, containing the individuals' hypothesis on how to successfully interact with the environment. The evolution of such mental models is a complicated process, strongly influenced by the nature of management behaviour.

6.9.1 A differentiation-oriented strategy in a company requires much local adaptability and creativity, linked to an effective exploitation that does not result in efficiency loss in the industrial-based processes; it also requires a coherence with the company's strategic ambition and identity

6.9.2 The process of rule evolution is Holland's view a networked learning process. For an experienced network of agents, learning will only come from finding situations in which the current rule-set does not yield an adequate result[xvii]. Such deviations from experience will cause new rules to be tested.

6.9.3 In many of the networked systems the agents will be human. In human networked systems we are confronted with the need to obtain an understanding of the way in which individuals (and networked individuals as a subsystem) look, act and learn. The human brain is not very good at processing new information, but it is excellent in fast and effectively processing of known information. Each one of us has a mental model of reality, which enables us to rapidly understand information, decode it and act upon it. However, information that reaches us, which is not compatible with this mental model or violates it, is mostly lost.

6.9.4 The Parisian neuro-physiologist Francisco Varela has done extensive research into information processing in the brain and he comes to a similar conclusion (Varela, 1988). Apparently, 80% of the input is internally generated, and only 20% comes from signals we absorb from the outside world. As Levinthal and March (1993) put it, it is a question of enactment: what we do not know we do not see; what we do not want to see, we do not see. We are quite good at re-arranging observations in such a way that they become congruent with our mental model[xviii].

6.9.5 Figure 6-5 displays Stacey's (1993) representation of the learning cycle, which governs the normal evolution of our behaviour.

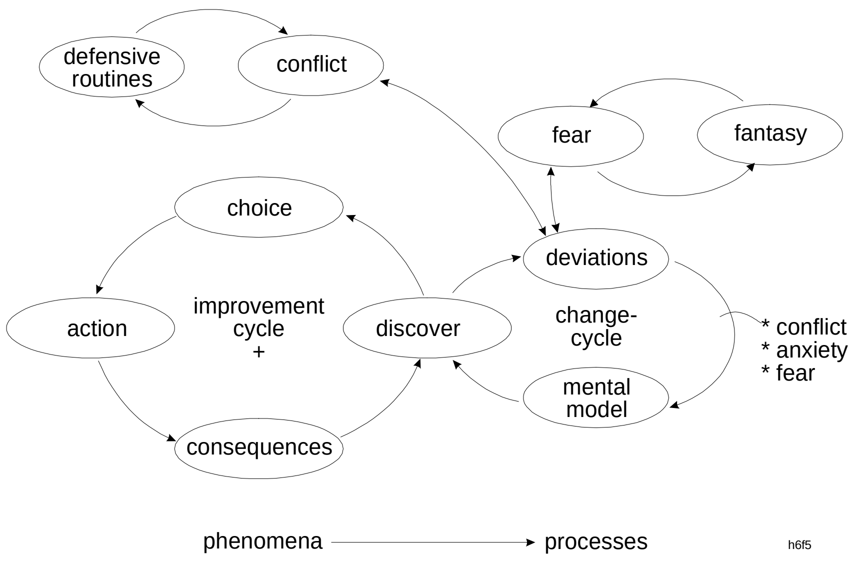

Figure 6-5: Double loop learning (source: Stacey, 1993)

6.9.6 We continuously loop the loop by the actions we take, the consequences we cause, the detection of the facts thereof, and the new choices we make, which we again turn into actions. The mental model plays a key role in this discovery, because normally (within the context of this mental model) we perceive only that which is consistent with this mental model, causing subsequent choices and actions, and their effects to be expressed within that same context. This learning process is driven by the importance the individual attaches to that process, but the direction of the learning process is dominantly governed by the content of the mental model. This learning circle enables us to improve the way in which we work and act within the confines of our perception of the outside world. This partly explains why change is so terribly difficult.

6.9.7 Sometimes, however, consequences and phenomena emerge which are no longer compatible with our existing mental model, and such a divergence triggers us to adjust it. These deviations cause implicit conflict and lead to confusion in observation and to anxiety about leaving the security and stability of our mental model. Therefore, change (which is changing the mental model) will always cause tension and conflict within an individual, as well as between individuals. Human beings and organisations alike consider this undesirable; to them it is a sign that situations become worse.

6.9.8 Both personally and collectively we have created defence mechanisms that prevent our mental model from changing; one of these mechanisms is swamping any hostility in defensive routines, in an endeavour to neutralise the conflict. Alternatively, there is the anxiety of fantasies which invokes an unreal world in which we are able to live with incongruities, rather than try and adjust our mental model. In many cases, these two mechanisms prevent deviations between observations and our mental model, which would change that model. Moreover, withdrawal into defensive routines takes the pressure off the divergence that would lead to alteration of the change circle in the learning process; these defensive routines therefore remove the company from the edge of complexity to the centre of stability and homogeneity.

6.9.9 One of those defence mechanisms is enactment, or the creation of an 'own environment' or a private, comprehensible world. In this way, they can maintain their existing mental models for longer times, because their enacted environment does not change as fast as the real world.

6.9.10 Or, as Levinthal and March (1993) put it

"Problems that are not seen do not exist. Or at least, their manifestations are delayed, and being delayed are likely to be transformed over time - possibly becoming more severe and unavoidable, but also possibly becoming irrelevant or minor."

However, in one way or another, at some point a mental model becomes unsustainable, and the organisation's competencies become irrelevant.

6.9.11 The improvement cycle (the left-hand cycle in Figure 6-5) is able to function properly on the basis of power (expressed in terms of an individual's physiological needs, sense of security and position within a group). In contrast, the right-hand cycle will be governed for the most part by self-interest and particularly by the individual's ability to manifest and distinguish himself within the group. The latter implies that:

- Under conditions of unpredictability there will be a growing emphasis on the right hand loop (change) causing self-interest to become more important than power as the base for professional behaviour;
- It implies that egalitarian-oriented organisations, where positive and negative discrepancies in a group are being levelled away, must have enormous problems in becoming networked structures.

6.9.12 While the left-hand side of the process could be defined as ‘fathering’, ‘mothering’ is associated with the right-hand side. On the left the process is concerned with details; on the right, attention is given specifically to the shape of processes, because there is no possibility to directly influence the mental model of the people concerned. The model develops through the processing of deviations between reality and the model. Removal of these deviations, therefore, kills all learning on the right side of the diagram.

6.10 Complex rules : Boolean structures and credit assignment

Mental models can be seen as a set of IF/THEN rules, linked together by Bolean operators. In order to make the evolution of the mental model goal oriented, some form of credit assignment (equivalencies) in the exchange is required.

6.10.1 Kauffman (1993) states that when Boole formulated his binary laws, it became clear that with a small number of Boolean functions such as 'AND', 'OR' 'IF, 'NOT', all logic could be derived. Boolean operators are mathematical operators, of which many have the values 'TRUE or FALSE'. Boolean[xix] structures are combinations of Boolean operators in one expression. For example:

" IF A rather than B or C and not D THEN action."

is a rule with a number of Boolean operators.

6.10.2 In the evolution agents will memorise successful rules and complex sets of such rules will develop in time, combining possible events and actions in nested Boolean structures.

6.10.3 The ability to remember what is and what is not successful, is essential in a learning process (e.g. in buying a house, buying behaviour in a supermarket) Rules must be successful in achieving non-zero sum value, as well as in serving the self-interest of the agent.

6.10.4 Alternative propositions for entering exchange relations may occur. Thibaut and Kelly's theory (1959) [xx] then suggests that in evaluating the outcomes of an exchange relation, agents use two expectation levels:

- The expectation level for the current relation, based on previous experiences and on assessment of future results;
- The expectation level for alternative relations, based on the lowest level of results that the agent will accept, given the available alternatives.

6.10.5 Holland adheres to the view that rules are hypotheses, undergoing testing and confirmation. Here the objective is to provide contradictions, rather than to avoid them. The rules amount to alternative, competing hypotheses. But if there is competition, there must be also a means to resolve it. Holland states that this means that rules must be experience-based. Credit assignment reflects the rules' usefulness to the system over time.

6.10.6 While credit assignment is relatively easy with direct pay-off for actions, it becomes increasingly difficult with (longer-term) indirect pay-offs, rules that act simultaneously, etc. Holland uses the metaphor of a 'supply chain' of rules, in which each rule buys and sells messages. When a rule buys a message ('IF' condition), it must pay from its cash; i.e. its strength is reduced. When a rule sells a message ('THEN' condition), its strength is increased by the amount received. Competition is introduced through a bidding process. This way rules are inforced that contribute to a reward in the end.

6.10.7 The bidding will depend positively on both the strength and the specificity of the rule. Common rules are fairly easy to find, and thus are tested quite frequently, so that credit assignment will quickly designate appropriate strength [xxi]. However, rules that are more specific will take progressively longer to find and establish[xxii]. Out of this a rule hierarchy results, hence some form of nested Bolean structure.

6.10.8 By operant conditioning (a technique of behavioural conditioning through manipulation of the consequences of previous behaviour, through re-inforcement), agents can formulate responses to a diversity of environmental stimuli. Homans' generalisation proposition states that similar stimuli generate similar responses:

> *"If in the past the occurrence of a particular stimulus, or set of stimuli, has been the occasion on which a person's action has been rewarded, then the more similar the present stimuli are to the past ones, the more likely the person is to perform the action, or some similar action."*
> (Homans, 1974 [xxiii]).

A second proposition is that for all actions taken by persons, the more often a particular action of a person is rewarded, the more likely the person is to perform that action.

6.10.9 By providing rule interaction the IF-THEN rules generate the full potential of a programming language: all behaviour open to the agent can be determined. An agent can be described as a set of message-processing rules. Some rules are detector-originated (external stimulus), some rules generate effectors (external results), and some rules activate other rules.

6.10.10 Holland:

> *"A particular agent is described by setting down the cluster of rules [...] that generate its behaviour. Rules so defined act much as instructions in a computer, the cluster serving as a program that determines the agent's behaviour. If there is any way to model an agent on a computer, these technical conditions guarantee that it can be modelled using a cluster of rules in this format."*

6.10.11 Rules can be assumed to be binary strings: IF (rule string, e.g. 10101) THEN (message string, e.g. 00000).

Holland:

> *["[...] our intent is not to claim that we can locate the rules explicitly in the real agents. Rules are simply a convenient way to describe agent strategies. A major part in the modelling effort for any complex adaptive system, then, goes into selecting and representing stimuli and responses [...]."*

6.11 Recombination and proliferation

The effective evolution of organisational know-how is greatly enhanced by the ability to recombine successful new rules with existing rules throughout the organisation.

6.11.1 As argued earlier, industrial organisations are good at exploitation and relatively weak in exploration and innovation, whereas decentralised organisations are completely the opposite. Complex adaptive organisations quickly acquire the knowledge of how to sustain achievements, and, combined with a high level of coherence, the ability to manage risk through evolution.

6.11.2 Here we see an important difference with the traditional idea of Darwin's evolution theory. Darwin thought that the evolution mechanism was based on ‘survival of the fittest’. Modern insight in the evolution of organisms points out, however, that it is not so much the momentary fitness of a species which is important for survival; but rather its capacity to evolve by adapting to the changing future. Ability to evolve is thus the core of survival power for a complex adaptive organisation. For the complex adaptive organisation, emphasis in management lies on the ability to select, code and diffuse information in the form of rules. The ability to combine speed with memory and coherence, thereby having the best of both worlds, is the key to breaking the traditional exploitation/exploration dilemma.

6.11.3 According to Holland (1995), rule generating is not a random process; newly generated rules must have some plausibility. This plausibility arises from the use of previously tested building blocks that appear in strong rules. Thus, strong rules can be seen as 'parents' for new rules. A second idea is that, just as 'offspring' is not identical to the 'parents', crossing-over interaction will take place.

6.11.4 Holland states that to simulate the process of producing a new generation [of rules] from the current one, we have to use the following three steps [xxiv]:

- *Reproduction according to fitness.*
  Select strings from the current population to act as parents. The fitter the string, the more likely it is to be chosen as a parent. A given string of high fitness may be a parent several times;
- *Recombination.*
  The parent strings are paired, crossed and mutated to produce offspring strings;
- *Replacement.*
  The offspring strings replace randomly chosen strings in the current population. This cycle is repeated over and over to produce a succession of generations.

6.11.5 The difference between an industrial, sequentially working organisation and a decentralised, parallel-operating organisation is evident when it comes to the breadth of the innovation front, where innovations are shaped. While in an industrial sequentially working organisation they have a quantum-step type character, in a decentralised, parallel organisation they are manifested by a large series of experiments and initiatives. On the basis of survival of the fittest or the ablest to evolve, a number of them will survive. Where the industrial sequentially working organisation lacks the ability to use the distributed intelligence in the organisation, the decentralised parallel organisation lacks the ability to create coherence and consistency in the innovation process.

6.11.6 The latter aspect, especially, distinguishes fundamentally the complex adaptive organisation from the organisation, which only deploys parallel processing. In Chapter 5.2 we stated that the difference is found in the ability to select innovations, code them and diffuse them. Complex adaptive organisations are able to distinguish good innovations from bad ones, provided ‘better’ or ‘worse’ can be measured, as without such measure any reference to ‘better’ or ‘worse’ is meaningless. It is important to note that the selection mechanism and measure of success lie outside the innovation mechanism, because it is impossible for innovations to select their own internal reference. This is because an endogenous measure of success in the innovation process secures its conditioning and thus reduces the chances of broader exploitation of local intelligence.

6.11.7 With regard to innovations (particularly the parts which have caused the success in terms of the hypothesis or measure) it is not necessarily immediately clear which part of the rule set forms the core in this respect. Such innovations can represent a group of activities and initiatives as well as complex interaction with the environment.

6.11.8 It is like looking at a series of Picasso paintings. One way or another, we recognise all works in the series as Picassos, but we have great difficulty in explaining why! As long as the core of innovation success is not captured, it is very difficult to disseminate, other than through people who can relate the story of the innovation within him. In this sense stories, like Picasso's art, are an important vehicle of communication, but they rely strongly on the ability of others to distil the core out of the story and adapt it to their own situation.

6.11.9 Such diffusion mechanisms are slow and relatively incongruent; moreover, it highlights the considerable disadvantage that as an organism the organisation has no memory for change. Again, each situation has to be addressed with un-coded stories and the experiment and initiative reconstructed from scratch, which seems, at least partly, like reinventing the wheel. In addition, because success cannot be decomposed into its components, the organisation loses its ability to re-mix elements of different solutions to recombination techniques as a hypothesis for even better innovations. As is the case, for example, with genetic algorithms in biology (sexual transmission of properties) and the human immune system, this recombinant mechanism is responsible for the ability to evolve very rapidly in extremely complex search spaces. The finding of a solution, by genetic algorithms, in four or five generations and even in a search space of 2^{60}, is not exceptional. However, it would be impossible on the basis of simply transference and trying out complete strings of codes in new situations.

6.11.10 Hence, if we want to acquire complex adaptive organisational behaviour, it is not only necessary to create a situation in which innovation emerges (this is an almost automatic consequence of the shift to parallel processing). We must also be able to select these innovations and put them into order. After that, to the extent in which they can qualitatively contribute to the goals that have been set and subsequently to code, these innovations can achieve the desired recombinant and fast convergence in complex situations in the search process. Finally, meaningful, coded and successful innovations must be distributed throughout the rest of the organisation by diffusion mechanisms, otherwise all this leads to nothing. Push-driven diffusion processes do not work; they destroy the parallel processing mechanism of the organisation, which then falls back on the traditional procedural industrial form. Successful solutions, therefore, will have to be proliferated through a pull-mechanism, in order to find their way to reorganisation. Such a pull-mechanism means interest in or desire for ideas and experiences with which the units can help themselves to achieve their aims. This implies that apart from outrageous goals for the respective units, a non-egalitarian culture is necessary to overcome the ‘not invented here’ syndrome.

6.11.11 Romer (1995) uses the computer metaphor to distinguish among three broad classes of inputs: hardware, software, and wetter. Whereas hardware includes all traditional, physical objects used in production (e.g. capital equipment, raw materials, infra-structure), wetter captures what economists call 'human capital' and what cognitive scientists refer to as 'tacit knowledge'. It includes all the things stored in the 'wet' computer of the human brain. The third element - software - includes all the knowledge that has been codified and can be transmitted to others: literal computer code, blueprints, operating instructions, scientific principles, folk wisdom, films, books, music, language, etc. It can be stored as text or drawings on paper, as images on film, or as strings of bits on a computer disk or laser disc.

6.11.12 Software has always contributed to production, even in the days before digital electronics brought it dramatically to the fore. For example, in the 19th century textile factories software for guiding the actions of a power loom was stored on wooden cards with holes punched into them. In a broader sense, workers followed explicit instructions which they learned from managers, teachers and colleagues.

6.11.13 The story about titmice and robins, which happened in the UK, as quoted in De Geus (1997), illustrates the speed of adaptation nicely. Robins found out how they could open milk bottles. By enacting their swarm behaviour they transmitted the code for this trick throughout the whole robins population very quickly. This was to the detriment of titmice, who discovered the trick, too. But as their behaviour is territorial, it prevented the code from being transferred and every titmice colony had to discover the trick for itself. As a consequence, robins have retained the size of their population, while titmice have been decimated

6.11.14 Another example is agriculture. In the last hundred years, some improvements in productivity can be traced to improvements in hardware (machines, fertilisers, etc.). But ever since the Neolithic revolution, people have been accumulating software on how to grow crops and manage domesticated animals. This software accumulated through trial-and-error and spread orally.

6.11.15 Romer (1995) stresses the importance of evolutionary innovation:

> *“The most misleading aspect of the factory model of economic activity is the suggestion that all of the instructions - all of the software - in any production activity can be discovered and perfected from the beginning."*

This is the traditional industrial engineering point of view. Just how much scope there is for the discovery of new software becomes clear if we think of the strings stored on a computer disk. Each position in the string is binary, i.e. 0 or 1. If the disk has room for two bits, it can hold $2 * 2 = 4$ different programs: {0,0}, {0,1}, {1,0}, and {1,1}. If the disk has room for 10 bits, it can store 210 = 1024 different programs. A typical computer hard disk has room for millions of bits; the number of programs that can be stored on a 1Gb hard disk is roughly a one followed by 2.7 billion zeros. This number can be compared to the age of the universe, which is estimated roughly at a number that consists of a one followed by 17 zeros.

6.11.16 The ability to explore vast, near infinite, solution spaces becomes very important in creating solutions to policies for networked systems interacting under conditions of extreme heterogeneity and unpredictability. In order to address extreme variety in the market place, a richness of solutions will have to be generated in the company processes which processes therefore need to explore a ver large solution space, be it in supply chain processes, information processes as well as organisation processes. The implications of these will be addressed in section C in the Chapters 9 through 12.

6.11.17 Assembly operations can involve thousands of parts, generating billions of possible assembly sequences, most of which have never been tried. While many of them would be worse than the currently used sequences, there will be others that would generate important efficiency gains. These alternative sequences can only be discovered by workers on the assembly line, by experimentation. To transform this 'tacit knowledge' into new software, managers should encourage workers to experiment with alternative sequences and to communicate their successes to others.

6.11.18 The ability to select, code and diffuse by use of pull-mechanisms is the core of complex adaptive working organisation. It gives the organisation a memory and takes care of coherence in innovation and development, of which the energy generated is largely decentralised.

6.11.19 Analogous to natural systems, the business environment can in the short term be considered as a resource or a constraint to business projects. Much more crucial, Duening (1997) states, is the long-term role of the environment in selecting 'good ideas' (i.e. organisational structures, systems or procedures). Resembling that of genetic evolution and selection [xxv].

6.11.20 As Baaij and Commandeur (1997) rightly state, a company is not an organism, an therefore the whole idea of applying the concept of genetic evolution is strictly taken inappropriate. Baaij and Commandeur (1997) work out the concept of memes: 'As Penrose has already indicated, management and organisational signs lack an element which is comparable to the concept of genes. Dawkins (1976) has resolved this shortcoming with the concept of 'memes'. Memes are to be considered as building blocks of the mental evolution. These memes are the smallest transferable information entities. With respect to this, one could think, for example, about words, manners, ideas. Knowledge and experience are to be considered memes. The function of memes in the memitical evolution is comparable to that of the genes in genetic evolution. Just as the genetic evolution is built from cycles of variation, selection and replication of genes, the memes evolution consists of variation, selection and replication of memen. And just as the genotype is a specific configuration of genes, in the same way: and memotype is a specific configuration of the memes' (Baaij and Commandeur, 1997). In this view, a company would be a 'memotype'.

6.11.21 Duening:

> *"Perhaps the organisational equivalent to the gene is the meme, which is a bit of knowledge or cultural artefact."*

Reproduction of memes means evolutionary success. Duening states that by careful analysis of the 'market selectors', managers can experiment with and create memes that have a better chance to succeed than others. To adapt, corporations need to change their 'genetic' coding. This means changing basic assumptions about industry structure; ways of making money in the industry; who the competitors are; who the customers are; what customers want and what they don't want; which technologies are relevant and which are not; adapting beliefs, values and norms about how best to motivate people; adapting the balance between internal co-operation and competition, adapting the relative ranking of shareholder, customer and employee interests; changing ideas of what behaviours to encourage and discourage (see also Hamel and Prahalad, 1994).

6.11.22 Analogous to natural systems, the business environment can in the short term be considered as a resource or a constraint to business projects. Much more crucial, Duening (1997) states, is the long-term role of the environment in selecting 'good ideas' (i.e. organisational structures, systems or procedures). This process resembles that of genetic evolution and selection.

6.12 Conclusions

6.12.1 In this chapter the various mechanisms underlying emergent order in organisations were described. From the description of these mechanisms it becomes clear that self-organising properties of organisations are by no means automatic, and require careful design. Careful design in discriminating between the various mechanisms required creating this emergent order, but also careful design with respect to the way in which such networked structures are managed.

6.12.2 Not just a style of management, but also the setting of goals and the management of the equivalency exchange in the networked structure are of determining importance for order to emerge. Seen in this way emergent order is not the rule but the exception, and will only arise if a particular set of circumstances can and will be created.

6.12.3 In this chapter though we addressed the emergence of networked order at the level of the individual entities. However companies can be considered as coalitions between various networked subsystems (shareholders, employees and clients) or as a collection of business processes which form such networked subsystems in their own right. In the next chapter we will address specific issues which relate to the interfacing between subsystems of a different nature. Although for such subsystems principles of this chapter apply as well, there are a number of peculiar areas of interest that should be addressed before we can embark on exploring the applications of such ideas in the future business processes.

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[i] One exception to this is Burt (1992). In his book 'Structural holes: the social structure of competition', he analyses the efficiency and effectiveness of using networked relations as seen from the individual. Structural holes (lack of connectivity between sub-systems) are in his view the key determinant to design effective and efficient networked relations. Although his view in interesting from a general perspective, it does hardly contribute to our understanding of emergent order in networked structures.

[ii] For a systematic treatment of network research, we refer to Fombrun (1982). He distinguishes between two kinds of networks: attribute networks, linking individuals that share some common attribute transactional networks, focusing on the exchanges occurring among a set of individuals
In his article he focuses on transactional networks, for this is the preferred initial strategy of organisational research by many researchers.

[iii] According to Hannah and Kay the following requirements apply to measures of concentration: ranking criterion, sales transfer principle, entry condition, merger condition. The contribution of a company to concentration tends to zero as the stake in the branch turn-over approaches zero.

[iv] Van Hulst and Willems (1989) mention the following measures of concentration: the concentration ratio, the Hirschman-Herfindahl index, the Rosenbluth index, the organisational entropy index and the index of Hannah and Kay.

[v] Van Hulst and Willems' (1989) entropy index is equal to the way we calculate entropy, i.e.
$E = - \sum s_i * \log s_l \quad (i = 1 \rightarrow n)$
The index of Hannah and Kay is different in that it is a reverse index and that the weights of the entities can be adjusted (by varying α): $HK(\alpha) = (\sum s_l^{\alpha})^{1/(1-\alpha)}$, $(i = 1 \rightarrow n)$, where $\alpha > 0$, $\alpha \neq 1$.

[vi] Swanson, Bailey and Miller (1997) reason that what they call 'money-information markers' can be used to measure social-economic organisational entropy in organisations. Social organisational entropy shows that social entities have a number of distinct features, which operate to ensure that organisational entropy levels remain below maximum. One of those components is information. Money, in turn, is in social-economic systems an important source of information, in that it refers to exchange values. Money-information can thus be used to measure exchange of concrete elements among societal components, such as organisations. This provides a measurement of the organisational entropy of the social system structure (the more exchanges, the larger the organisational entropy, the larger the disorder). Within organisations, these exchange values are 'spent' as they are conversed into products and services. This is a process of decreasing organisational entropy (or, as Swanson, Bailey and Miller refer to it, negorganisational entropy). To describe social-economic systems as they emerge through exchange processes, both measurements of negorganisational entropy and organisational entropy are needed, the first referring to the forming of social-economic systems, the second to the structural organisational entropy occurring over time in these systems. In modern, market-based societies, these measurements - as they are financial in nature - can be mapped in double-entry bookkeeping systems. On a more abstract level, they are conceptualised in terms of the utility that the various forms of matter-energy (goods-services) and money-information markers (monetary assets) provide to a social entity. In the economic process, these utilities are measured in financial terms. Therefore, the accounting system provides information on the entropic changes in the system, to be used for policy, control, or forecasting purposes.

[vii] Knoke and Kuklinski (1982).

[viii] Examples are the generation of complementary values, meaningful exchange of values, added value arising from co-operation, added value off-setting energy investments, equivalent exchange, availability of behavioural rules for interaction.

[ix] This, in fact, is the basis of international trade; our entire market economy is based on this notion. In other words: the theory of international trade dictates that every country should specialise in that which it is relatively best at. As companies evolve towards higher complexity, this is reflected in their defining core competencies and core businesses, and therefore defining which specialities they perform best (see also Markusen and Melvin, 1988).

[x] These phenomena were already observed in economic processes by the so called ‘Scottish thinkers’, Smith, Ferguson and Mandeville. Mandeville (1714) stated that when everyone would pursue his own self-interest this would automatically lead to optimisation for the whole (compare Smith’s “invisible hand’ argument and Ferguson’s quote in Chapter 8.7.7.

[xi] Quoted in: Peelen, 1989.

[xii] Compare the ‘selfishness’ of genes (Dawkins, 1976).

[xiii] Goals judged as impossible under the current configuration of co-operation, but attainable if only we want to

[xiv] Theoretically, knowledge can be converted between tacit and explicit in four possible modes (Nonaka, 1994):

- From tacit to tacit: socialisation
- From tacit to explicit: externalisation
- From explicit to tacit: internalisation
- From explicit to explicit: combination
  When managed well, these conversions can reinforce each other by dynamic interaction, resulting in what Nonaka calls the 'spiral of knowledge'. The capacity of the organisation to convert implicit rule-following by people into explicit knowledge is the key to organisational knowledge creation (Nonaka, Takeuchi and Umemoto, 1996)

[xv] Complex adaptive systems (Holland, 1995) are made up of a large number of active elements called 'agents'. The behaviour of these agents can be described by a collection of stimulus-response rules: IF stimulus s, THEN give response r. Agents adapt by changing their rules as experience accumulates.
Holland states:
"It is useful to think of an agent's behaviour as determined by a collection of rules, in the form of stimulus-response rules (IF-THEN). To define the set of stimulus-response rules possible for a given agent, we must describe the stimuli that the agent can receive and the responses it can give. Though stimulus-response rules are limited in scope, there are simple ways of expanding that scope. Indeed, with minor changes, the scope can be enlarged sufficiently that clusters of rules can generate any behaviour that can be computationally described."
If rules are to provide a uniform way of representing the capabilities of different agents, they have to contain a number of criteria:

- Rules must use a single syntax to describe all complex adaptive systems agents
- The rule syntax must provide for all interactions among agents
- There must be an acceptable procedure for adaptively modifying the rules

In general the form of these IF-THEN rules is co-operative. In contrast to structured processes where such rules are instruction rules, no interaction is required within the line of process.

[xvi] For a further description of Axelrod and the relevance for networked structures see Chapter 7.8.

[xvii] This is another expression of the need for ‘outrageous’ goals

[xviii] This refers to Verhaegen’s (1984) notion of uncertainty. Instead of trying to translate uncertainty to the certainty of a mental model, companies and agents have to learn to deal with uncertainty.

[xix] It is not sure that the combination between all “IF’s” and all “THEN’s” with all possible Bolean operators will yield al possible rule sets. Similarly as the Turing machine has been proven not to produce all thinkable arithmetic operators. Yet, as a first approximation of possible rules, this definiton will likely be sufficient.

[xx] According to Thibaut and Kelly (1959) the existing of the relation itself, too, can be expressed in IF-THEN terms, in the form of the following possible behavioural rules:

- IF results > expectations (current) > expectations (alternative)
  THEN satisfaction. Continue relation
- IF results > expectations (current) AND results < expectations (alternative) THEN dissatisfaction.
  Discontinue relation; choose alternative relation
- IF results < expectations (current) AND results > expectations (alternative) THEN dissatisfaction. Continue relation involuntarily.
- IF results < expectations (current) AND results < expectations (alternative) THEN dissatisfaction. Discontinue relation; no new relations

[xxi] For example, in a rule space where each position can take the value 0 or 1 or # (indifferent), the rule [1####] will be satisfied half of the time, and thus be tested quite frequently.

[xxii] As an example: condition [10111] will be satisfied only one out of 32 times, leading to slower credit assignment.

[xxiii] Quoted in: Peelen, 1989.

[xxiv] To give an illustration of this mechanism of rule production, consider the following example (Holland, 1995). Again rules consist of strings. Each position in a string can take the values 0 or 1 r # (indifferent). A * on a position means any of these values. These positions are however not relevant to the fitness of the string.
In this example, the fitness of a string directly determines the number of offspring, and the average fitness of the overall population is equal to 1, so that the average string produces 1 offspring. The first step in genetic algorithms involves reproduction.
Consider the building block 1 * * * * * *, which has just three instances in the initial population, with finesses 1, 0, and 1 respectively. The three instances of 1 * * * * * * will produce a total of 1 + 0 + 1 = 2 offspring, or an average of 2/3 offspring per instance. Because these are the only strings carrying the building block 1 * * * * * *, that building block will have only two instances in the new generation. This could be predicted, because the average strength of 2/3 is less than the average strength of 1 of the total population. To see what happens when numbers change, consider the building block * 0 * # # * * and assume it has also three instances, with finesses 2, 2, and 1, respectively. The three instances will produce a total of 2 + 2 + 1 = 5 offspring, or an average of 5/3 offspring per instance. Again, the outcome is as can be predicted from the strengths: 5/3 is greater than 1, so there should be indeed more instances of * 0 * # # * * in the next generation.
So the fittest strings produce most offspring. This seems precisely the result desired, so why complicate the procedure by adding the second step of crossover? The reason is this: the reproduction in step 1 simply copies strings already present; it does not produce any new combinations, so the agent would be limited to the best of strings present in the initial population. No matter how large the initial population, this can only be a minuscule sample of the possibilities. In a complex, changing environment, an agent using only reproduction is unlikely to fare well against agents that can generate new hypotheses. That is where the crossover effect comes in. The third step, replacement or mutation, is necessary because under reproduction and crossover it is possible for a given schema (e.g. 0 * * * * * *) to become present in every member of the population ('fixation'). Then, we have no strings starting with 1 or #. In the set of all possible strings, only 1/3 starts with 0, so we reduced to trying out possibilities in only 1/3 of the space. Random mutation of positions in a string covers for this effect.

[xxv] The evolution is that of the 'selfish' genes (Dawkins, 1976), that serve their own interest by forming a genotype and thus achieving synergy. The genotype is the genetic core of the organism, the configuration of genes whereas the phenotype is the outer appearance, the visible characteristics. The phenotype is the result of the interaction between the genotype and its natural surroundings. The surroundings select only the outer appearance, the phenotype. However, in Dawkins' view, the phenotype is the 'survival machine' that enables the genotype to survive.