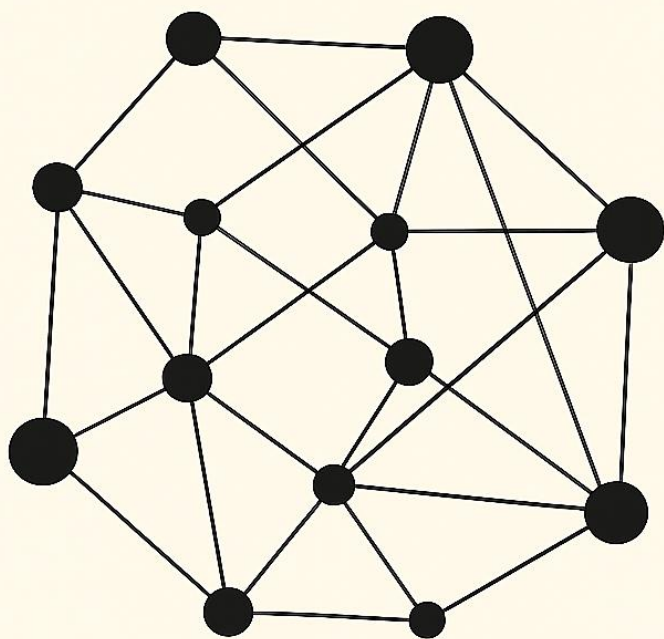


Concepts of Complexity

A Very Short Introduction



Michael Frahm

Concepts of complexity

for T,F,A²



Concepts of complexity

A very brief introduction

Michael Frahm



Imprint:

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Foreword

The book was written during discussions and presentations as part of my association work. I have repeatedly realised that those involved, as well as myself, usually only know one or two handfuls of actors who have dealt with complexity. The same names often came up, such as *Wiener*, *Ashby*, *Bateson*, *Beer*, *von Foerster* and, in German-speaking countries, mainly *Luhmann*. I found this to be one-sided and the desire grew in me to dig deeper into the topic and the various actors.

The starting point was the book by *Ramage* and *Shipp* "Systems Thinkers" which provides a very good overview of 30 different thinkers and assigns each of them to a school of thought (cybernetics, general systems theory, etc...) over several pages and also describes the respective actor on the basis of his original writings. At the same time, of course, I studied the Map of Complexity Sciences by *Castellani* and *Gerrit*, which contains an incredible wealth of actors and links. Almost too many for my taste. I then worked through *Mike C. Jackson's* book "Critical Systems Thinking and the Management of Complexity", which describes actors, origins and interrelationships very apodictically and is highly recommended, but at around 700 pages is not an easy read. This was followed by books on the development of the Santa Fe Institute, including "Complexity: The Emerging Science at the Edge of Order and Chaos" by *M. Mitchell Waldrop* and the book "What is a complex system" by *Ladyman* and *Wiesner*. Finally, I studied the books by *Fritjof Capra*, in particular his work "The Systems View of Life". All in all, this has resulted in several years of reading and discussion, and a map of relevant actors has emerged that I carry with me and whose connections I can understand.

This book is not intended to be a classic or a standard work, nor is it a scientific book. It is questionable whether it even deserves the name "book", or whether it would be better called a booklet. It is intended to be an easy introduction. As easy as it can be and should introduce a number of actors on 1 to 2 pages who have made a contribution to dealing with complexity. One thing can also be said: the book is incomplete. There are certainly actors missing who are very important and inspiring for one or the other. Yes, it is a fact that this work is incomplete, but anyone who looks at *Castallani* and *Gerrit's* "Map of Complexity Sciences" will know that if you want to write a short and easy introduction to the subject, you have to make a selection and it will be incomplete. That is in the nature of things. To be honest, there are a few more names on my list, both historical and contemporary, but the delimitation is as

it is for this edition, especially to keep the text manageable. As the 1st edition is a "very short introduction", perhaps in a subsequent edition actors will be added to the list, which I will point out and which can join the company of the luminaries. And perhaps at some point a "very short introduction" will become a "short introduction".

The next topic is the categorisation and classification of the respective school of thought. Here, too, there will certainly be critics who say that it is not correct to assign this or that actor to this school of thought. Many actors can also be assigned to several categories, e.g. *Fredmund Malik*, who is of course a cyberneticist, but has also made important contributions to management. In principle, I have based my categorisation on the above-mentioned works, which often make a reservation. This is not an exact scientific categorisation; the field of dogmatic work is left to others. Nevertheless, the categorisation is of a practical nature and helpful for creating your own map in your head.

My personal recommendation for reading the booklet is as follows: Always read one actor and then reflect on it over a week and consult other sources. There is now a wealth of good information on the Internet about every actor. Whether videos, articles, Wikipedia entries, books, etc.. I recommend this approach, as it allows the reader to follow the development of the book a little. The book does not have to be read in a linear fashion, you can read the actors as you like. The most important thing, even if it is a short introduction, is that reading and reflecting does not have to be quick, it should serve your own realisation.

Introduction

The quote from Stephan Hawking sums it up well:

"I think the next century will be the century of complexity."

Complexity is no longer an abstract concept. Complexity characterises our networked everyday life, our society, our technology and our self-image like never before. Ignoring complexity means standing still. Those who understand it will shape the future.

Anyone who has read this book will have a better overview of different concepts for dealing with complexity and will perceive, understand and discover complexity for themselves from different perspectives. The book contains eleven different categories and 36 actors from different areas. Each of the actors has contributed in their own way, with one or more concepts for dealing with complexity. A concept is understood here as an idea, a model, a specific approach or central principles that offer an approach to understanding or dealing with complexity.

Complexity is not explicitly defined here, as many different areas have different approaches and definitions of complexity. For example, the computer scientist associates complexity with computational effort, the sommelier with depth of flavour in wine and the management cyberneticist thinks of Ashby's Law of Requisite Variety. However, properties that express complexity are mentioned, these are: Self-organisation, emergence, no central control, nested structures, adaptability, robustness, non-linearity, path dependency and many different elements and interactions. If you would like to learn more about these properties, I recommend the book "What is a complex system" by *Ladyman* and *Wiesner*. A longer section of the book is dedicated to the properties.

As I said, this text does not provide a generally valid definition of complexity, but it does offer a non mathematical rule of thumb. In the two decades that I have been dealing with the facets of complexity, the following rule of thumb has emerged for me:

$$C = (E * B * V)(t)$$

Where C stands for complexity, E for elements, B for relationships of the elements, V for behaviour of the relationships and (t) for temporal change.

If there is a social system, e.g. a company, with 100 employees (E = elements) who have different formal and informal relationships (B) with each other and who behave differently in these relationships (V), I have a basic idea of the structure of complexity according to the rule of thumb. If we now consider that this social system changes over time (t), then we have an idea of the dynamics. The temporal change (t) plays a major role.

The company used as an example is a rather slow example in terms of change over time. Changes consist of people being hired, leaving the company or changing departments, to name just a few possibilities for change. This sluggish dynamic can change abruptly if, for example, customers or markets collapse. Or, in another example, if you have these 100 hundred people walking in one place and suddenly, from one second to the next, panic breaks out. This is a rapid temporal change (t) that expresses the dynamics that complexity can have. Regardless of this, complexity, especially in social systems, is and remains subjective and dependent on the perception and experience of the observer. Everyone perceives complexity differently.

Complex systems are considered to be, for example: Anthills, the human brain, the Internet and our home planet Earth, to name just a few examples. Machines are not considered complex. A classic example is the car, which is not subject to change over time. Its behaviour is predictable and trivial from a complexity perspective. If I steer to the right, it drives to the right. This is called complicated. Traffic, on the other hand, is complex; in every car there is an individual who reacts independently and not always rationally. The behaviour of one vehicle has an influence on the behaviour of other vehicles and the behaviour of the system is therefore only partially or not at all predictable.

In order to understand complexity, this book presents eleven schools of thought or categories that deal with the complex. Following the eleven categories, it begins with the natural sciences as the basis for a fundamental understanding of complexity and chaos with *Poincaré*, *Lorenz* and *Mandelbrot*. This is followed by general systems theory with *Bertalanffy* and *Boulding*, who recognised the interrelationships in systems and the need to name them. The early cybernetics of *Wiener*, *McCulloch*, *Ashby* and *Bateson* laid the foundation for understanding complexity by focussing on feedback and control. Late cybernetics with *von Foerster*, *Beer* and *Maturana* emphasised self-referentiality, organisation and autopoiesis. Systems Dynamics around *Forrester*, *Medows* and *Senge* further developed the modelling of complex systems through feedback loops and simulations. The complexity theory around *Prigogine*, *Holland*, *Kaufmann*, *Snowden* and *Bar-Yam* contributes to the understanding of emergent orders, non-linear dynamics and complex adaptive systems. In

psychology, sociology and philosophy with *Lewin*, *Luhmann* and *Mainzer*, systemic and complexity theory approaches are applied to social, cognitive and societal processes.

The contribution of *Lovelock*, *Vester*, *Margulis* and *Capra's* understanding of biological and ecological systems provides new insights into the self-regulation, networking and interactions of living systems as well as the holistic nature of ecological processes. Hard Systems, Soft Systems and Critical Systems Thinking with *Ackoff*, *Checkland* and *Jackson* expanded systemic thinking through methodical approaches to problem solving, participatory modelling and critical reflection on complex systems. Management around *Drucker*, *Ulrich*, *Malik* and *Stacey* combines systemic thinking with effective leadership and adaptive organisation. Contemporary systemic counselling with *Fritz B. Simon* and systems practice with *Patrick Hoverstadt* bring much of the elegant theories into practice. Unfortunately, female actors have been underrepresented in the past. A fact that will hopefully change in the present.

The text on the actors always follows the same triad, the general, non-concluding brief introduction to the actor with an extract of key findings. The resulting concept of dealing with complexity and finally some ideas that inspire practical action. At the end of each actor there is a reflection question and a mini-exercise in the footnote. Finally, there is a summary, a brief overview and a selected recommendation for literature and online content.

From the outset, the aim of the book was to write no more than 120 pages, somehow a number that invites rather than discourages reading on this overpowering topic. The goal of the number of pages succeeded, but led to the constant process of weighing up what not to write. You could say the difference that makes the difference here was in the less. The book hopefully makes a difference and encourages the reader to dive deeper into the rabbit hole of complexity, understand it better and utilise this understanding to shape the future.

Natural sciences



Henri Poincaré

The French mathematician *Henri Poincaré* (1854-1912) is considered the founder of chaos theory. During his investigations into the stability of the solar system, he discovered deterministic chaos. The mechanistic view of the world was predominant in the scientific world at the time, characterised by the French physicist and astronomer *Pierre-Simon Laplace* (1749-1827), among others. *Laplace* held the idea that the universe could be completely calculated like a giant machine with the help of a world formula. It is all the more remarkable that *Poincaré* came to the conclusion during his creative period that small differences in the initial conditions can lead to large deviations in the result. He thus questioned the idea that a complete calculation of the future was possible solely on the basis of present conditions.

While Laplace's demon - a hypothetical being - would theoretically be able to predict all future events, *Poincaré* showed that this does not work in real systems. In doing so, he disproved a central assumption of classical

determinism and created the basis for a new understanding of complex and dynamic systems. *Poincaré* thus showed that precise predictions in complex systems are only possible to a limited extent.

Concept: *Henri Poincaré* showed that dynamic systems react sensitively to the smallest changes in their initial conditions and can be unpredictable in the long term. He thus laid the foundations for chaos theory and made a significant contribution to the understanding of complex systems.

Practical action: Develop sensitivity for the smallest changes and so-called weak signals. Weak signals are subtle, often inconspicuous indications of possible future developments or changes in the system. They can be the first signs of major upheavals long before they become obvious. It requires attention, openness and a culture of observation to recognise these signals early on and interpret them correctly. Example: Management notices that employees are increasingly sharing new ideas in informal conversations, such as in the coffee kitchen or in chats, rather than in regular meetings. This could be a weak signal for a change in internal communication or a need for different, more flexible or innovative working methods. Mindful management could respond to this by testing new communication formats and creating creative freedom. A conscious approach to such micro-observations can help to recognise trends at an early stage, proactively shape change processes and strengthen the adaptability of complex systems.¹

¹ **Reflection question:** Where in your life do you trust in predictability even though you know deep down that things will turn out differently?

Mini-exercise: Choose a situation that you have planned precisely. Observe where small deviations appear and what they might mean. What unexpected order do you recognise in it?



Edward N. Lorenz

Edward N. Lorenz (1917-2008), an American mathematician and meteorologist, also observed that even the smallest changes in initial conditions could lead to major deviations in his weather forecasts. This realisation gave rise to the popular term "butterfly effect". The underlying mathematical structure was named after him as the Lorenz attractor. This is a so-called strange attractor, which is based on three coupled non-linear ordinary differential equations. The Lorenz attractor describes the solutions towards which the system moves in the long term. Its shape is reminiscent of a butterfly.

Lorenz's discoveries show that chaos is not to be equated with randomness; rather, it reveals patterns and regularities (see also *Poincaré's* deterministic chaos) that have fundamentally changed our understanding of dynamics and predictability. The Lorenz attractor also shows that complex systems create order and thus defy the second law of thermodynamics.

Concept: Lorenz' concept for dealing with complexity is based on the realisation that complex systems react sensitively to small changes (butterfly

effect), but nevertheless exhibit patterns and structures (Lorenz attractor) that help to better understand their behaviour.

Practical action: Regularly monitor dynamics in complex systems. Example: As predictions are only possible to a limited extent, systems must be continuously monitored and adapted. This applies in particular to large-scale and mega projects, where suitable risk management strategies are required, especially those that take into account black-swan events and fat-tail risks.

Recognising patterns in chaos. Example: Even in seemingly unpredictable systems, there are recurring structures that can be utilised, e.g. in weather forecasting by analysing patterns in climate data.

Use simulations. Example: Due to the sensitivity to initial conditions, modelling such as Monte Carlo simulations help to evaluate future scenarios under uncertainty.²

² **Reflection question:** When was the last time you realised that a tiny decision moved your whole system without you having planned it?

Mini-exercise: Sketch out two possible daily routines that run differently with just one small decision.



Benoît Mandelbrot

Benoît Mandelbrot (1924-2010) coined the term fractal structure and showed that previously inadequately described complex structures have the same properties as self-similarity. The mathematical expression of the Mandelbrot set is shown in the equation below. This can be used to perform the iterations that lead to the typical Mandelbrot fractal, where c stands for the complex numbers (point from the complex plane).

$$z_0 = 0; z_{n+1} = z_n^2 + c$$

He also made his work on fractal geometry accessible to the general public, so that today many people know about the fractal properties of nature (coastlines, plants, crystals, etc.). The following well-known quotation goes back to him:

"Clouds are not spheres, mountains are not cones, and lightning does not travel in a straight line. The complexity of nature's shapes differs in kind, not merely degree, from that of the shapes of ordinary geometry, the geometry of fractal shapes"

Natural structures are created through iterative processes and the repetition of simple rules, which leads to patterns. Nature uses fractals to optimise resources, for example in the supply of blood vessels, the structure of the lungs and the root system of plants.

Concept: Mandelbrot shows that complex systems are structured by repeated patterns and self-similarity. These fractal principles help to recognise order in chaos and to understand and design complex structures efficiently.

Practical action: Use fractal organisational structures. Example: Companies can orientate themselves on natural systems and create organisations with similar structures and control functions by applying the Viable System Model.

Develop scalable solutions. Example: Design solutions in such a way that they can be used repeatedly at different levels of a system and still offer possibilities for adaptation, e.g. by means of standardisation and modularisation.³

³ **Reflection question:** What repeats itself in your life on different levels and what meaning do you give to these patterns?

Mini exercise: Find an object in your environment (plant, tree, river, building) with fractal properties. Draw or photograph it.

General systems theory



Ludwig von Bertalanffy

Ludwig von Bertalanffy (1901-1972), Austrian biologist and systems theorist, is considered the founder of general systems theory. He used it to identify common principles such as complexity, self-organisation, feedback and various states of equilibrium in physical, social and biological systems.

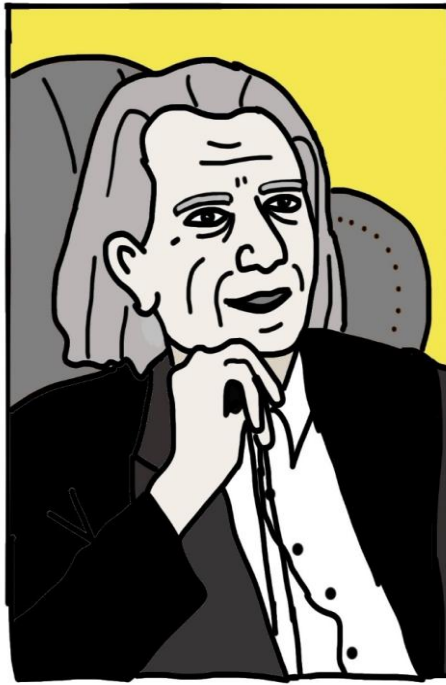
During his doctoral studies in Vienna, he was influenced by the idea of "unified science", a common language for all sciences. With his own work, he broke through the boundaries of individual disciplines, searched for overarching connections in order to better understand complexity and created an understanding of systems. *Bertalanffy* believed that living systems are open systems that maintain their stability through the exchange of matter with the environment and are subject to a dynamic equilibrium. He borrowed this approach from thermodynamics, an idea that later found its way back into thermodynamics through *Ilya Prigogine*. His concepts led to a paradigm shift, as he recognised early on how essential systemic thinking is.

Concept: *Bertalanffy* emphasises that complex systems remain dynamically stable and adapt through interactions, self-organisation and open exchange with their environment. He attaches great importance to the interdisciplinary approach, common language and shared understanding.

Practical action: Promote interdisciplinary collaboration by integrating different perspectives and specialisms. Example: A research project on sustainable urban development brings together experts from the fields of civil engineering, architecture, urban planning and environmental sciences to develop resource-saving, social and environmentally friendly solutions for cities through intelligent transport systems, energy-efficient buildings and sustainable infrastructure. Not only technical expertise is brought in, but socio-economic and ecological aspects are also taken into account. Regular dialogue and a common language between the disciplines creates a holistic understanding that enables innovation and practical solutions. The participation of citizens, politics and business is also sought in order to make the implementation sustainable and adaptable in the long term.⁴

⁴ **Reflection question:** Where in your thinking do new connections arise when you bring different disciplines together?

Mini-exercise: Describe a system (e.g. your family, your team, your club) as an open system. Where does exchange take place?



Kenneth Boulding

Kenneth Boulding (1910-1993) was a British-American economist and one of the pioneers of interdisciplinary research. He shaped systemic thinking in economics and social sciences. He also worked intensively on ecology, ethics and sustainable economics. In his influential essay "General Systems Theory - The Skeleton of Science (1956)", he presented a cross-system perspective that identifies common structures and laws in different disciplines.

Boulding realised that complex systems cannot be viewed in isolation, but exist in a network of interactions. He was an advocate of holistic thinking and argued that understanding systems requires thinking across disciplinary boundaries. He was a recognised outsider in the field of economics and, like *Bertalanffy*, is considered a co-founder of general systems theory.

Concept: *Kenneth Boulding's* systemic thinking can be described as "systemic sustainability". He viewed the world as a network of interconnected systems whose stability is ensured through communication, sustainable development and social and ecological interactions. Instead of optimising individual systems in isolation, he emphasised the importance of their interactions for long-term sustainable solutions. For him, the economy,

ecology and society are inextricably linked and embedded in an overarching system of cyclical processes, resource utilisation and feedback effects.

Practical action: Promoting the sustainable use of resources through a circular economy. Example: Increased use of recycled materials in production and prioritising waste avoidance. Nature serves as a role model here, as it produces no waste and every material is returned to the natural cycle. This principle has inspired concepts such as cradle-to-cradle design, which aims to design products in such a way that all materials can be fully recycled. Permaculture, which promotes sustainable agricultural systems through closed cycles, also follows this logic

In order to put this thinking into practice, business, science, politics and civil society need to work closely together. Companies can contribute to resource conservation through innovative product design, transparent supply chains and extended product life cycles. Education and information also play a key role in promoting awareness of systemic interrelationships and sustainable behaviour at all levels. The aim is to transform the linear models of "produce → consume → dispose" into circular models with "produce → consume → reuse", thereby ensuring ecological and economic stability.⁵

⁵ **Reflection question:** What if you saw the world as an interconnected system?

Mini-exercise: List 3 systems in which you operate. How are they interrelated? Where do they complement or interfere with each other?

Early cybernetics



Norbert Wiener

Norbert Wiener (1894-1964), an American mathematician, introduced the term cybernetics (from the Greek κυβερνήτης/ kybernetes, helmsman - navigator of a ship). Alongside many other scientific greats (*Bateson, von Foerster, McCulloch, Shannon, von Neumann*, etc.) of the time, he was a member of the interdisciplinary Macy Conference, at which the term cybernetics was also agreed upon for the interdisciplinary control of systems. *Wiener* himself was concerned with control and regulation in technical, biological and social systems, and was particularly interested in feedback.

His book "Cybernetics or Control and Communication in the Animal and the Machine" was published in 1948 and dealt with the feedback analogies and communication processes in machines (e.g. thermostat) and in humans (e.g. brain). Through his work, he dealt with topics of big data, machine pattern recognition and artificial intelligence at an early stage and thus made an important contribution to today's information society. Cybernetics is more

relevant than ever, as it is about understanding the control mechanisms in systems in terms of a mathematical theory of communication.

Concept: *Norbert Wiener's* approach to dealing with complexity is based on an understanding of positive and negative feedback, the black box principle, the central role of information, and an interdisciplinary approach to the control, communication and prediction of complex, dynamic systems in both technical and biological contexts.

Practical action: Using feedback means stabilising systems through negative feedback and thus reacting to changes or deviations in a targeted manner. An illustrative example is a thermostat: it continuously measures the room temperature and intervenes to regulate it as soon as it deviates from the desired value, for example by switching the heating on or off. Social or organisational systems can also be designed according to this principle. In companies, for example, a quality control system can be implemented that recognises errors or deviations in the production process at an early stage, provides feedback and enables targeted corrections to be made. This form of feedback not only ensures stability in the system, but also opens up opportunities for learning and improvement. By reacting quickly to problems, quality is not only assured, but ideally continuously improved. Feedback is therefore a central principle for resilience, adaptability and development in complex systems.⁶

⁶ **Reflection question:** What feedback in your everyday life do you ignore, even though it could guide you?

Mini-exercise: Identify a feedback loop in your everyday life today (e.g. thermostat, feedback dialogue). Observe its effect.



Warren McCulloch

Warren *McCulloch* (1898-1969) was an American neurophysiologist and cyberneticist who founded artificial intelligence with his work in the field of neuroinformatics. He played a leading role in the Macy Conferences. He was a founding member of the American Society for Cybernetics and worked with *Gregory Bateson*, *Norbert Wiener*, *Humberto Maturana* and *Stafford Beer* (to name a few). He made significant contributions to neural networks, automata theory and cybernetics. He originated the principle of the:

"Redundancy of Potential Command - power resides where information resides".

Power can also be exchanged for decision-making authority. Neural networks are the model for this. His collaboration with *Walter Pitts* led to the development of the *McCulloch-Pitts neuron* (1943), one of the first formal models of artificial neurons, which forms the basis for modern artificial neural networks. His work significantly influenced *John von Neumann*, particularly in the development of the *von Neumann architecture* for computers. *McCulloch* also laid important theoretical foundations for self-organisation and information processing in the brain, which were later developed further by *Humberto Maturana* and *Francisco Varela* in their concept of autopoiesis.

Concept: *McCulloch's* concept for dealing with complexity is based on the principle of: *"Redundancy of Potential Command"*, which means

understanding information processing as a decentralised, distributed system in which decisions are made where the most relevant information is available.

Practical action: Design decentralised networks for information processing. Example: Companies such as Uber work with decentralised platforms on which drivers interact directly with customers instead of relying on central control.

Apply principles from neural networks for information processing. Example: Companies such as Amazon or Google use AI-supported systems that use distributed neural networks to process large amounts of data in parallel in order to identify patterns in customer behaviour. Modern organisational structures in companies such as Haier or Spotify also follow this principle by relying on small, autonomous teams that process information independently and make decisions decentrally, similar to neurons in the brain.⁷

⁷ **Reflection question:** Where in your life would it be wiser to make decentralised decisions and how would you make this possible?

Mini-exercise: Make a decision today and ask yourself: Where does the information for this lie, with you or someone else?



Ross Ashby

Ross Ashby (1903-1972) was a British psychiatrist and a pioneer of cybernetics. He belonged to the circle of the Macy Conferences and contributed significantly to the understanding of control and regulation in complex systems. The brain played a central role in his work as a model for self-organisation, homeostasis and ultrastability. He is particularly well known for the "Law of Requisite Variety", also known as *Ashby's Law*. The law states:

"Only Variety can absorb Variety".

In concrete terms, this means that a system must have at least as much variety of action as is available in its environment in order to be able to act effectively. If this adaptability is lacking, the system can become unstable or suffer from a loss of control. *Ashby* considered this principle primarily from a mathematical perspective in the context of information processing. The associated variety theorem is as follows:

$$V_c \geq V_e$$

V_c (variety controlling) describes the control capability of a system.

Ve (variety environment) stands for the variety of the environment with which the system interacts.

For a system to remain stable, the control variety must be greater than or equal to the environmental variety ($V_c \geq V_e$). This principle has far-reaching consequences for management and systems theory. *Stafford Beer* translated *Ashby's Law* into practical use for management with the Viable System Model. *Beer* was also the one who argued in favour of *Ashby's* concept of variety as a metric for measuring complexity. *Ashby's* law is still considered one of the most fundamental principles of systems science today. It also plays a decisive role in artificial intelligence (adaptive systems, machine learning and decision-making under uncertainty) because it shows that artificial intelligence can only operate successfully if it has sufficient decision-making and reaction options to cope with the diversity and unpredictability of its environment. Some consider the significance of *Ashby's Law* to be as fundamental as *Einstein's* $E = mc^2$.

Concept: *Ashby's* concept for dealing with complexity is based on the Law of Requisite Variety. This means either increasing, reducing or directing complexity to where it can be processed most effectively.

Practical action: Variety management: The targeted control of complexity is essential to make systems efficient and adaptable. Depending on the requirements, it can make sense to increase, reduce or specifically focus complexity. Too little variety can mean that a system is not flexible enough to react to changes, while too much complexity can cause unnecessary costs and inefficiency. Balanced variety management makes it possible to dynamically adapt structures and find the optimum balance between flexibility and stability. Example: In the IT industry, a system is designed in such a way that it dynamically adapts its processing capacity. When data volumes are high, additional resources are automatically provided to ensure stable performance. In times of lower utilisation, the system in turn reduces its capacity in order to save energy and costs. As a result, the system not only remains powerful, but also economically efficient and sustainable.⁸

⁸ **Reflection question:** What do you need in order to not only keep up with the variety of your environment, but to consciously shape it?

Mini-exercise: Take a challenge and write it down: What options for action do you have? How could you increase variety?



Gregory Bateson

Gregory Bateson (1904-1980), British anthropologist, biologist and social scientist, is regarded as an important thinker in interdisciplinary systems research. With his "Ecology of Mind" approach, he analysed the patterns and communication processes that connect biological, psychological and social systems. For *Bateson*, systems are shaped by interactions, feedback and learning. His double bind theory, which explains how paradoxical communication patterns can favour mental disorders, is particularly influential. *Bateson* searches for common principles in evolutionary, cognitive and ecological processes. His approach represents a paradigm shift by demonstrating that systems do not exist in isolation, but are linked to each other through relationships and patterns. The following quote from him is very apt:

"What is the pattern that connects the crab to the lobster and the primrose to the orchid, and all of them to me, and me to you?"

He asked about the patterns that connect and does not focus on the elements but rather on their connections. Another of his statements is:

"Information is a difference that makes a difference".

This statement encourages us to focus on identifying and understanding those differences that actually have an impact on results, be it in communication or decision-making.

Concept: *Gregory Bateson* tackles complexity by focussing not on elements, but on the underlying patterns and relationships. He scrutinises the connections that these patterns create.

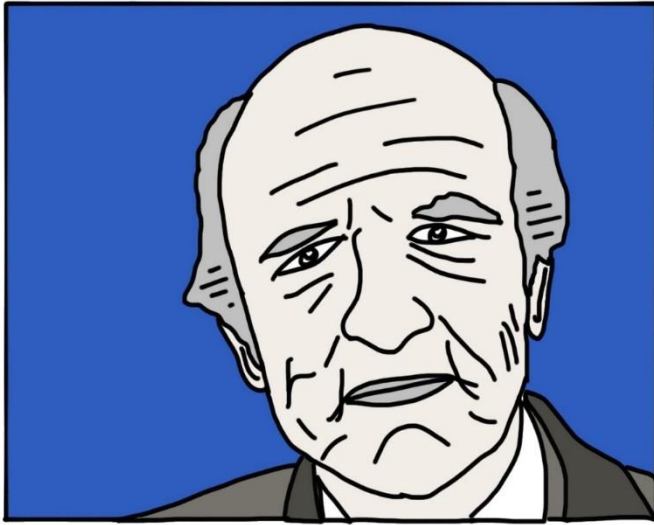
Practical action: Looking at problems in the context of their interactions. Example: *Bateson's* double bind theory shows that contradictory messages can create destructive patterns. In companies, for example, it leads to a loss of trust if openness is demanded but critical feedback is penalised. A deeper analysis of communication structures helps to recognise and resolve such patterns.

Example: *Bateson* showed that a frog recognises a threat not by individual stimuli, but by patterns of movement. Applied to companies, this means that falling sales can rarely be attributed to a single factor. If you recognise patterns in customer behaviour, market changes or internal communication, you can develop targeted solutions.⁹

⁹ **Reflection question:** What is the unifying pattern in your relationships that you have not yet named?

Mini-exercise: Observe a conversation. Don't pay attention to content, but only to patterns of interaction. What do you recognise?

Late cybernetics



Heinz von Foerster

Heinz von Foerster (1911-2002) was an Austrian physicist and played an important role in the development of cybernetics and radical constructivism. He was a member of the Macy Conferences and served as editor of the associated conference proceedings. In particular, *von Foerster* coined second-order cybernetics, in which the observer of a system is regarded as part of the system. It says: Be aware that you are part of the system, every observation and action can change the system. This perspective requires that the observer's influence on the system is included in the description. If another observer also observes both the system and the first observer, this is referred to as "observation of observation". This approach makes it clear that perception and cognition are not objective, but are always characterised by the respective observer.

Another important contribution by *Foerster* is his ethical imperative, which reads as follows:

"Always act in a way that increases the number of choices!"

This imperative calls for making intelligent decisions and increasing the variety of options for action. It is a strong instruction for action that encourages

us to consider the impact of decisions on the future and the various interests involved.

Concept: *Foerster's* approach to dealing with complexity is based on second-order cybernetics and the ethical imperative. This means recognising oneself as part of the system, questioning one's own perception and making decisions in such a way that they open up new options.

Practical action: Reflecting on observation, i.e. recognising that every observation influences the system and questioning one's own position as an observer. Example: A scientist not only analyses a social phenomenon, but also reflects on how his own assumptions and methods help to shape the results.

Expand options for action, i.e. organise decisions in such a way that they open up more possibilities instead of restricting them. Example: A car manufacturer relies on a modular platform strategy in which different vehicle models are produced on a common basis in order to react more quickly to market requirements and introduce new variants with minimal development effort.¹⁰

¹⁰ **Reflection question:** How do your actions change when you accept that you can never observe neutrally?

Mini exercise: Reflect on a situation in which yourself were part of the system that you were observing. What did you see and what did you overlook, what influence did your observation have?



Stafford Beer

Stafford Beer (1926-2002) was a British cyberneticist who is regarded as the founder of management cybernetics and made significant contributions to the understanding of complex systems with important concepts such as the Viable System Model (VSM) and Syntegration. For *Beer*, cybernetics was the science of effective organisation. In Chile, he attempted to establish the Cybersyn project, which aimed to realise cybernetic control of the entire economy. However, this project was brought to an end by the political upheaval of 1973.

The Viable System Model he developed is used to analyse and design organisations and to manage complexity in an entrepreneurial context. It describes organisations as self-sustaining systems that continuously adapt to changing environmental conditions. The model is also recursive, which means that each organisational unit has similar control mechanisms to the overall system, resulting in a scalable and adaptive structure. Finally, the VSM functions as a homeostat that maintains a dynamic balance through closed feedback loops and reacts flexibly to change. These principles make it possible to establish organisations as resilient, self-regulating and adaptive systems.

Another of *Beer's* key concepts is Syntegration, a process for collaborative decision-making and problem-solving in complex systems. The term is made up of "synergy" and "integration" and describes a method in which groups interact with each other in a specially structured form in order

to generate as many perspectives and ideas as possible. Syntegration avoids hierarchical decision-making processes and instead favours equal, networked communication between the participants. This structured interaction allows the collective intelligence of the group to be optimally utilised in order to develop creative and sustainable solutions to complex challenges. The basis is the icosahedron, a geometric body with 12 corners and 30 connections, which ensures equal networking. Each of the 12 corners, for example, represents a participant that is directly connected to five others. This highly interconnected structure promotes a change of perspective and enables dynamic topic processing, allowing collective intelligence to be utilised effectively.

Concept: *Stafford Beer's Viable System Model (VSM)* is the model of a control organisation that masters complexity through self-organising structures, feedback loops and recursiveness in order to ensure adaptability and stability. Furthermore, its concept of Syntegration enables all perspectives to be integrated into complex decision-making processes in a decentralised manner through structured communication.

Practical action: Integration of a control organisation to manage complexity. Group example: At Bosch Mobility Solutions, the VSM is used to establish organisation-wide agility.

Example of major projects: The VSM can be used to create the management organisation for major infrastructure projects. It enables the alignment of actors with different interests and the creation of a temporary organisation that produces the best result for the project in terms of structure, process and control organisation.

Example SME: At JELBA Werkzeug- u. Maschinenbau, a medium-sized contract manufacturer, VSM is used to align the company operationally and strategically to the complexity of contract manufacturing (many one-off and customised products).¹¹

¹¹ **Reflection question:** If your system was twice as complex tomorrow, what would you rely on to ensure that your actions still work?

Mini-exercise: Sketch your own Viable System Model (5 system levels, 6 info channels)



Humberto Maturana

The Chilean biologist *Humberto Maturana* (1928-2021) was instrumental in addressing the question of when systems are alive and when they are not. Together with *Francisco J. Varela*, *Maturana* introduced the concept of autopoiesis. Autopoiesis refers to the ability of a system to generate and maintain itself from within itself. Autopoietic systems are able to constantly reproduce themselves and maintain their own structures without losing their identity. A crucial property of autopoietic systems is their ability to couple themselves structurally with their environment. This means that the system and its environment are connected in such a way that they develop or orientate themselves in the same direction. This structural coupling enables the system to adapt to changes in its environment and maintain its autopoiesis. The ability to structurally couple with the environment is an essential property for coping with complexity. *Maturana's* theories have influenced *Heinz von Foerster*, *Niklas Luhmann* and many others.

Concept: *Maturana's* concept for dealing with complexity is based on autopoiesis and structural coupling. A system is autopoietic if it can generate itself from itself and maintain its structures. Structural coupling describes the mutual adaptation of a system to its environment. This coupling enables the system to continuously change while maintaining its identity.

Practical action: self-organisation through collective interaction. Wikipedia is an example of autopoiesis and structural coupling in practice. The platform is not controlled by a central authority, but is organised through the collective interaction of a global community of users. These users create, edit and update content on their own initiative. Wikipedia is constantly growing and changing through the contributions of the community, without the need for external control.

The quality of the content is monitored by mechanisms such as discussion pages, maintenance categories and deletion requests. The community ensures that incorrect information is corrected and unobjective content is removed. In this way, Wikipedia remains a dynamic, self-renewing system that continuously adapts to new information, social changes and technological developments. Wikipedia remains stable and functional, while at the same time interacting closely with its environment.¹²

¹² **Reflection question:** What keeps you alive and how do you create relationships that support this vitality?

Mini-exercise: Think of a relationship in your life. What is structurally linked to it? How does one change with the other?

System Dynamics



Jay Wright Forrester

Jay Wright Forrester (1918-2016), an American computer- and systems scientist, is considered the founder of the systems approach "System Dynamics". He developed this in the 1950s and founded the "System Dynamics Group" at the Massachusetts Institute of Technology (MIT) at the Sloan School of Management. *Forrester* was a pioneer in the application of quantitative methods to understand and model complex interactions within systems.

With the help of flow charts and mathematical models, Forrester was able to depict and simulate the dynamics of systems in order to analyse the effects of decisions and changes on the entire system. He emphasised the importance of quantitative analysis in order to analyse and solve problems in complex social, economic and technical systems. He placed particular emphasis on the mathematical nature of his models in order to enable precise predictions and in-depth insights. Today, system dynamics is widely used in various

fields, such as environmental policy and corporate management, and is regarded as a valuable method for modelling and controlling complex, dynamic processes.

Concept: With System Dynamics, *Forrester* developed a concept with feedback loops (mathematically "positive" for reinforcement and mathematically "negative" for stabilisation) and stocks and flows (stocks and their inflows and outflows) to model interactions within systems. Mathematical modelling and simulations can be used to analyse, display and design non-linear behaviour and delays in cause-and-effect chains.

Practical action: Observing economic cycles in the property market. Example: Rising prices lead to increased investment during a boom. Over time, the market becomes saturated, demand falls and a recession occurs. Interest rate policy and lending influence these cycles. Low interest rates facilitate borrowing and encourage investment during a boom. Rising interest rates make loans more expensive, reduce demand and can thus trigger or intensify a recession. Delays in construction and overreactions by investors reinforce these cycles, as was seen in the property bubble during the global financial crisis in 2007/2008.

Recognising the bullwhip effect in supply chain management. Example: An IT company expects demand for a new software version to increase and orders more licences as a precaution. The IT department then increases server capacity and orders additional hardware. External service providers expand their infrastructure in order to be prepared for the increased demand. In reality, however, the increase in demand is only short-term, which leads to overcapacity and high operating costs. The company is left with unutilised resources and long-term contractual obligations. Effective communication along the supply chain, real-time data analysis and needs-based ordering processes with lower safety stocks can counteract this.¹³

¹³ **Reflection question:** What cycles (loops) in your life are you aware of?

Mini-exercise: Draw a diagram for a situation with feedback. Where are reinforcing and where are stabilising loops? Are there delayed reactions?



Donella Meadows

Donella Meadows (1941-2001) was an American biophysicist and systems scientist who became well known for her contribution to the 1972 report „The Limits of Growth“ for the Club of Rome. *Meadows* led the team of researchers at MIT who modelled the global limits to growth using the System Dynamics method on behalf of the Club of Rome. She was a student of *Jay W. Forrester*, the founder of System Dynamics, and worked with him on research into complex, feedback systems.

Meadows was an early advocate of systems research and sustainability as tools for overcoming complex challenges. She lived privately on an organic farm and combined theory with practice. Her posthumously published book: *Thinking in Systems. A Primer* (2008, edited by *Diana Wright*) is considered a popular key work for systemic thinking. In this book, she describes the so-called "leverage points" within a system. These are strategic points at which even small changes can have a major impact on the entire system. Her theory is based on the sensitivity analysis of complex systems, as researched by *Henri Poincaré* (dynamic systems, chaos theory) and *Edward N. Lorenz* (deterministic chaos, weather models). While *Poincaré* and *Lorenz* concentrated on mathematical and physical modelling, *Meadows* transferred these findings to social, ecological and economic systems

According to *Meadows*, recognising and targeting leverage points is an effective way of solving networked problems. Meadows' levers include small changes in parameters, strengthening or weakening feedback loops, adjusting time delays, changing the distribution of information, changing system goals/modifying underlying assumptions in mental models and changing system boundaries.

Concept: *Donella Meadows* approaches complexity with systemic thinking. She views systems as networked structures whose behaviour is determined by feedback loops, time lags and interactions. Her concept of leverage points is an effective tool for bringing about far-reaching changes in complex systems.

Practical action: Reduction of CO₂ emissions in a city. Example leverage point: Changes in the distribution of information. If people are better informed about their energy consumption, for example through smart electricity meters and transparent carbon footprints that are not displayed in the basement but are clearly visible in living rooms or on mobile devices, they can use energy more consciously. Small changes in the behaviour of many individuals can have a major impact on the city's overall energy consumption.¹⁴

¹⁴ **Reflection question:** What lever could you move today that would have a big impact tomorrow?

Mini-exercise: Look for a "leverage point" in your environment today where you could make a big change with little effort. Write down an idea.



Peter Senge

Peter Senge (1947), an American management and systems scientist who belongs to the circle of System Dynamics pioneers around *Jay W. Forrester* from MIT, introduced systems approaches and in particular the System Dynamics method to the management world with his 1990 book "The Fifth Discipline". His systemic archetypes in particular caused quite a stir. *Senge* is a leading representative of learning organisations for coping with complexity. These are characterised by adaptability to internal and external stimuli and are formed on the basis of the five principles from *Senge's* book "The Fifth Discipline", which are: Personal Mastery, Mental Models, Shared Visioning, Team Learning and Systems Thinking. *Senge* describes Systems Thinking as the cornerstone for learning organisations.

Concept: *Peter Senge* proposes dealing with complexity through systems thinking by looking at interactions and recognising feedback loops. His systemic archetypes help to recognise patterns and think long-term. A learning organisation promotes continuous learning and the ability to adapt to change.

Practical action: Attention to archetypes. The archetype "tragedy of the commons" can occur in a matrix organisation.

Example: Different project teams compete for limited resources, such as specialist staff or budget funds, and primarily optimise their own interests instead of coordinating the use of resources in the interests of the organisation as a whole. This can lead to certain teams using an excessive amount of resources while others are disadvantaged. This makes the organisation as a whole inefficient. Prioritisation, resource planning and regular coordination processes defuse the dilemma.

Error culture and continuous learning. Example: An organisation could establish regular reflection and learning processes, such as carrying out a "retrospective" after every project or important decision-making process. This not only evaluates the result, but also examines the learning process and the causes of any problems. This reflection enables the organisation to learn from mistakes, recognise recurring patterns and improve its adaptability in order to better deal with complex situations in the future.¹⁵

¹⁵ **Reflection question:** Where will your organisation lead if it continues to learn the way it does today?

Mini-exercise: Observe a recurring chain of problems. Which systemic pattern (archetype) could this be?

Complexity theory



Ilya Prigogine

The Russian-Belgian chemist and Nobel Prize winner *Ilya Prigogine* (1917-2003) made lasting contributions to research into self-organisation and dissipative structures in open systems. His work revolutionised the understanding of thermodynamics, especially in systems far from thermodynamic equilibrium.

Prigogine focussed on irreversibility in dynamic processes and showed that order and structure can arise spontaneously if a system exchanges sufficient energy, matter or information with its environment. If this exchange is interrupted, the order disintegrates again. This contradicted classical thermodynamics, which only recognised an increase in entropy in isolated systems. His research was influenced by *Ludwig von Bertalanffy's* General Systems Theory, but went far beyond this through the mathematical modelling of non-linear processes.

Dissipative structures are ordered patterns that are self-organised in open systems. An example of this is a whirlpool in the bathtub when the drain plug is pulled and water flows out at the same time. The continuous exchange of energy and matter creates a stable, ordered structure (the spiral movement). However, this order only exists in a non-equilibrium state and disappears as

soon as the flow of energy is disrupted, a typical characteristic of dissipative structures.

Concept: According to *Prigogine*, order arises in open, non-linear systems through self-organisation, which is based on the exchange of energy, matter or information. This leads to phase transitions in which the system finds a new stable order. This makes many processes in nature irreversible; once complex structures have been created, they cannot simply return to their original state.

Practical action: Innovation networks and open innovation. Example: Procter & Gamble relies on the principle of open innovation, in which external ideas and solutions flow into the development processes. Similar to a dissipative structure, the exchange of information and resources with the environment is utilised. This approach promotes self-organisation in the development of new products and business models by integrating external sources of knowledge.

The exchange between companies and the environment is also a core driver of digital transformation. This means utilising process components from other companies to act quickly instead of owning the entire business process. In the industrial age, the focus was on an "inside → out" value stream; in the digital age, this is shifting to an "outside → in" value stream.¹⁶

¹⁶ **Reflection question:** Where do you observe order created by energy exchange between system and environment?

Mini-exercise: Allow chaos in a situation today without immediately creating order. What arises from this? What do you learn?



John H. Holland

The American computer scientist *John H. Holland* (1925-2015) is regarded as one of the founders of the concept of complex adaptive systems (CAS), which was developed at the interdisciplinary Santa Fe Institute. He describes CAS as follows:

"CAS (complex adaptive systems) are systems that have a large number of components, often called agents, that interact and adapt or learn."

Complex adaptive systems consist of numerous interconnected agents that make individual decisions, organise themselves and adapt to their environment. They exhibit self-similar structures, are capable of learning and continuously evolve. This concept is used in various scientific fields, including brain research (e.g. neuronal networks), biology (e.g. insect colonies) and organisational research (e.g. companies with decentralised decision-making structures).

Concept: *Holland's* concept for dealing with complexity is based on the theory of complex adaptive systems, in which many autonomous agents interact without central control and organise themselves. These systems are adaptive, learn from experience and adapt to changes. A central feature is

emergence, in which new, unpredictable structures and patterns can arise through the interactions of the agents.

Practical action: Adapting to market changes. Airbnb is an example of a complex adaptive system. Hosts, guests and the platform itself act as autonomous agents that shape the market through their interactions. Airbnb uses machine learning and data analyses to recognise shifts in demand in real time.

Based on these findings, hosts receive dynamic price recommendations so that the offer adapts flexibly to changing market conditions. Ratings optimise the quality of the offer without central control, while the system adapts its algorithms through continuous feedback analyses. The hosts' decentralised freedom of choice leads to flexible, dynamic market adaptation.

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¹⁷ **Reflection question:** In which area of your life could you place more trust in the self-organisation of a system?

Mini-exercise: Observe a system with many autonomous participants (e.g. road traffic, office, social media, family). Where do you see self-organisation?



Stuart Kauffman

The American biologist *Stuart Kauffman* (born 1939) is a trained physician and researcher in the field of complex systems. He worked at the Santa Fe Institute and later founded the BIOS Group. He worked for a time with *Warren McCulloch* at MIT and later met *Ross Ashby* at the University of Illinois. As a result, he was influenced by important representatives of cybernetics, which shaped his work on complexity theory.

Kauffman argues that self-organisation and path dependency through feedback effects play a decisive role in the emergence of complexity. This can arise spontaneously and independently of Darwinian selection. He made significant contributions to the concepts of complex adaptive systems, the "edge of chaos" and emergence. He also developed the concept of autocatalytic networks, which describes how chemical systems organise themselves through mutual catalysis and can thus possibly explain the origin of life.

Kauffman closely links the concept of emergence with self-organisation. He describes how new elements or system levels with specific properties emerge naturally in systems. The "edge of chaos" describes a narrow area between total order and total chaos, in which highly complex structures and dynamics can emerge. From the author's perspective, parallels to this can be found, for example, in *Dave Snowden's* Cynefin framework, particularly in the system state "Disorder", which deals with the categorisation of system states and complexity.

Kauffman's NK model describes complex systems that consist of many interacting components (N), whereby each interaction is influenced by an interaction (K). These interactions create a fitness landscape in which different states of the system have different fitness values. Fitness is the adaptive success of a system in a changing landscape/environment. Evolution and adaptation occur not only through random mutations, but also through the interactions between the components. The model illustrates how systems oscillate between order and chaos and develop dynamically. In addition to biological evolution, the model is also used in business and management to analyse innovation processes and decision-making structures.

Concept: *Stuart Kauffman's* concept for dealing with complexity emphasises that systems develop through self-organisation, not just through selection. He describes the "edge of chaos" as the optimal state for adaptation and innovation and uses the NK model to show how systems develop through interactions. He also explains how life can emerge spontaneously from autocatalytic networks.

Practical action: Technological development and artificial intelligence. Example: OpenAI is working on the development of advanced artificial intelligence that is improved through self-organised learning processes. The company uses machine learning and neural networks to develop systems that adapt to their environment without having to be programmed manually each time. This is in line with *Kauffman's* concept that systems evolve through the interactions of their components. OpenAI's GPT models are an example of how, through interactions within a network, a system can exhibit emergent, unexpected behaviours that are used to solve complex problems. Evolutionary algorithms that optimise themselves through natural selection and adaptation also reflect his theories.¹⁸

¹⁸ **Reflection question:** Where are you currently balancing between clarity and uncertainty?

Mini-exercise: Find the "edge of chaos" in your everyday life: Where is there creative tension between structure and freedom?



David Snowden

The Welsh consultant *David Snowden* (1954) became well known through an article published in 2007 in the *Harvard Business Review* in which he presented the Cynefin Framework. He describes his Cynefin (kə'nevin) framework as a concept for decision-making, which contains five domains/system states: Simple, Complicated, Complex, Chaotic, Disorder/ Disorganisation.

Depending on the situation you find yourself in, you can use it as a guide and derive actions from it, e.g. for complex system states: probe, sense, respond to break the system down into complicated subsystems, for example, and for chaotic system states: act, sense, respond to stabilise the system or move to a different system state, for example. The Cynefin framework enjoys great popularity due to its deliberate simplicity, especially in the scene around agile methods such as Scrum or similar, but also beyond.

In more recent work, *Snowden* integrates concepts such as Estuarine Mapping, a strategic navigation model for complex systems that he co-developed, as well as ideas from Constructor Theory from physics, which shifts the focus from fixed goals to spaces of possibility and systemic potential.

Concept: *Dave Snowden* describes complexity as an environment in which solutions emerge through interaction and must be discovered through experimentation and observation. He recommends paying attention to patterns, acting flexibly and navigating through the spaces of possibility that complexity offers.

Practical action: Experimental innovation in complex markets. Example: The company Interface, a manufacturer of carpet tiles, is pursuing the goal of developing sustainable products and promoting the circular economy. To this end, it converts recycled fishing nets into carpet tiles. In a complex system characterised by uncertainty and technological change, the company relies on an experimental approach, a principle recommended by *Dave Snowden* in the Cynefin framework for complex systems. The company follows a "probe, sense, respond" approach by continuously experimenting with new materials and manufacturing techniques.¹⁹

¹⁹ **Reflection question:** Which of your challenges is actually complex but you still treat it as if it were simple?

Mini-exercise: Take a current problem. Categorise it in the Cynefin model. Does your attitude to the approach change?



Yaneer Bar-Yam

Yaneer Bar-Yam (1959) is an American physicist and a pioneer of complexity research. He is the founder and president of the New England Complex Systems Institute (NECSI) and has made a significant contribution to the interdisciplinary analysis of complex systems. His work incorporates insights from physics, biology, sociology, economics and artificial intelligence to better understand highly interconnected and dynamic systems. *Bar-Yam* is particularly well known for his multi-scale analysis, which investigates how phenomena can arise and be controlled at different system levels. He showed that classic, centralised control mechanisms often fail when the environment requires a high degree of variety and adaptability. Instead, he emphasises the importance of decentralised decision-making structures, self-organisation and rapid feedback mechanisms for dealing with complex challenges.

A central principle of his research is: "*Interdependence drives complexity*", the interactions between individual elements of a system are the actual source of complexity. Emergent phenomena play a decisive role here, as simple rules at the micro level can lead to unexpected macro structures. His approaches have found application in areas such as financial markets, pandemic response, corporate strategy and AI-supported decision-making. For example, he analysed the dynamics of epidemics early on and developed

modelling to effectively contain diseases such as COVID-19. He has also shown that complex problems, from global supply chains to geopolitical crises, can only be understood and overcome through a systemic approach.

Concept: *Bar-Yam's* approach is based on the idea that complex systems regulate themselves on several levels simultaneously. Emergent phenomena and interdependencies play a central role in this. Instead of only reacting to local or global effects, adaptive systems must find the right balance between central control, decentralised decision-making and self-organisation. Fast feedback mechanisms are crucial for recognising and reacting to dynamics at an early stage.

Practical action: Adaptive control and resilience in complex systems. Example: In the financial sector, algorithms use multi-scale analyses to recognise and react to market volatility. While short-term fluctuations are balanced out by high-frequency trading, long-term forecasting models help to understand overarching trends. This enables dynamic adjustment of investment strategies and increases resilience to sudden crises

In addition, the combination of different time scales allows a holistic view of market events. Short-term data streams are processed in real time to make immediate decisions, while long-term analyses are based on fundamental indicators that emphasise stability and sustainability. This adaptive management not only promotes the resilience of individual market players, but also contributes to the stability of the entire financial system. Especially in times of global uncertainty or economic upheaval, the value of such systems, which can react flexibly to new information and still adhere to overarching strategies, becomes apparent.²⁰

²⁰ **Reflection question:** Where do you think linearly, even though your environment has long since reacted on several levels simultaneously?

Mini-exercise: Describe a problem on three levels (micro, meso, macro). What do you recognise anew?

Psychology, sociology and philosophy



Kurt Lewin

The German psychologist *Kurt Lewin* (1890-1947) is considered one of the founders of social psychology and made significant contributions to the understanding of group and change processes. He was closely networked with the founders of Gestalt psychology and took part in two Macy conferences, which also influenced him in the field of cybernetics. *Lewin* is credited with introducing the term feedback, which originally came from cybernetics, into common parlance. His field theory describes social systems as a dynamic interaction of different forces.

Lewin summarised this in the following formula:

$$V = f(P, U)$$

Behaviour (V) is a function of the person (P) and their environment (U), with both interacting with each other. Change processes within this field depend on the forces acting within it. The force field analysis he developed can be used to identify inhibiting and promoting forces in order to bring about targeted changes. Another central model is the 3-phase model of change (unfreezing - moving - freezing), which describes how changes are initiated, implemented and stabilised. *Lewin* also coined the quote:

"If you really want to understand something, try to change it."

Lewin also developed the action research approach, with which, for example, researchers and practitioners jointly analyse problems, test solutions, evaluate results and adapt the process iteratively. This results in practical and scientifically sound changes.

Concept: *Kurt Lewin* approached complexity with a systemic approach that views social systems as dynamic fields of influencing forces. His 3-phase model structures change processes, while the force field analysis shows that change is more effective when inhibiting forces are reduced instead of only driving forces being strengthened. With action research, *Lewin* also emphasised the importance of experimental learning and gradual adaptation. These approaches help to understand and control complex social dynamics.

Practical action: Action research in research. Example: In a research project on complexity management, the action research approach is used to investigate how companies can organise their processes and structures more efficiently. To this end, the existing corporate complexity is analysed and solutions such as process simplifications and IT optimisations are developed and implemented on a pilot basis in collaboration with employees. The effects of the changes are evaluated through continuous feedback and adjustments.

In addition, the change process is closely monitored by conducting regular reflection loops with the teams involved. These promote joint learning, strengthen the willingness to change and enable potential resistance to be identified at an early stage. The iterative approach allows new theoretical findings to be tested in practice in a timely manner.²¹

²¹ **Reflection question:** Which social forces are currently affecting you and which ones would you have to change in order to enable movement?

Mini exercise: Carry out a force field analysis: Which forces are currently holding you back, which are driving you forward? Draw them as arrows.



Niklas Luhmann

The German lawyer and sociologist *Niklas Luhmann* (1927-1998) made significant contributions to the understanding of social systems and their self-organisation. He was influenced by *Humberto Maturana* and his concept of autopoiesis, among others, and integrated central ideas of cybernetics into his systems theory. *Luhmann* describes social systems as autopoietic, self-referential units that operate through communication. Their development follows its own internal logic, which leads to path dependency, as systems stabilise themselves and only allow changes within their own structures.

In his work, he replaces the classic subject-object schema with the system and environment approach. Complexity arises because the environment always offers more possibilities than the system can process. He argues that complexity can be controlled through selection. The question of which information is useful leads to self-regulation and stabilisation of social systems

For *Luhmann*, communication is central to the constitution of systems. The concept of second-order observation originally comes from *Heinz von Foerster*, who developed it in cybernetics to describe the reflection of one's own observation process. *Luhmann* adopted this concept and explained that

social systems not only observe events, but also reflect on the criteria and conditions according to which they make these observations. This allows social structures and decision-making processes to be better understood and controlled.

Concept: *Niklas Luhmann* confronts complexity with an approach that understands social systems as autonomous, self-referential units. The reduction of complexity through selection is essential for social systems to remain capable of acting. With the theory of autopoiesis, *Luhmann* explains how social systems reproduce themselves through communication, while second-order observation shows that systems not only communicate, but also reflect on their own perception. These approaches make it possible to understand and specifically analyse complex social dynamics

Practical action: Managing complexity in organisations and choosing the right markets. Example: A company faced with increasing market complexity could apply *Luhmann's* complexity reduction approach by selectively choosing markets that better fit its strengths. By focussing on specific markets and differentiated offerings, it reduces alternatives and uncertainties, leading to a more effective use of resources and a better market position

In addition, the organisation can create or sensitise internal structures that are geared towards second-order observation. In other words, structures that not only make decisions, but also observe and reflect on their own decision-making processes. This enables the organisation not only to react to external changes, but also to adapt its own observation patterns. For example, a company operating in the technology sector can develop greater adaptability through targeted market observation and reflection on how it interprets and evaluates technological trends.²²

²² **Reflection question:** Which communication patterns determine your thinking without you having consciously chosen them?

Mini-exercise: Today, pay attention to communication patterns in a social system (e.g. work, family). What happens if you consciously break a pattern, e.g. through a paradox?



Klaus Mainzer

For the German mathematician and philosopher of science *Klaus Mainzer* (1949), complexity science is an integrative science that is universally valid. Complexity always contains many elements, regardless of whether they are cells, molecules, neurons or people. According to *Mainzer*, new patterns emerge in critical situations not only through the elements of a system, but also through their interactions. Complex systems in turn influence each other. Critical values in high-dimensional complex systems that lead to chaos are difficult to identify, as can be seen, for example, in climate models and social systems.

Chaotic systems in particular react sensitively to small changes. Predictions are fundamentally difficult, but nowadays they are made using computer simulations with supercomputers. He states that self-organisation can also be destructive, see cancer, which is self-organised but ultimately destroys its host and itself. In this context, balance is crucial and nature is a good example of this, see the predator/prey cycle. Early warning systems are therefore important for complex and chaotic systems in order to avoid critical situations.

Concept: *Klaus Mainzer* sees complexity as the result of dynamic interactions that are often non-linear and difficult to predict. In order to better

recognise critical thresholds and chaotic transitions, he emphasises the importance of early warning systems and computer simulations. At the same time, negative feedback is essential to keep systems stable.

Practical action: Artificial intelligence in traffic management. Example: Modern cities use AI-supported traffic management systems to control traffic more efficiently. Real-time data from sensors and cameras analyse traffic flows and dynamically adjust traffic lights or diversions. This reduces traffic jams, emissions and waiting times. Singapore, for example, relies on "smart traffic management", which uses AI to create traffic jam forecasts and optimise traffic flow. This adaptive approach follows *Mainzers* principles. Early warning systems, data analysis and self-regulating algorithms help to keep complex systems stable.

In addition, machine learning can be used to identify potential problem areas in traffic at an early stage before critical congestion occurs. Simulations make it possible to test various interventions in advance and better understand their impact on the entire system. The continuous feedback between data analysis and system control creates a flexible and resilient infrastructure that can adapt to changing conditions such as weather, roadworks or major events. This shows how technological solutions can make a concrete contribution to stabilising complex urban systems.²³

²³ **Reflection question:** Where do you recognise negative (stabilising) feedback loops in nature that keep systems that affect you in balance?

Mini-exercise: Draw a simple system with elements and their interactions (e.g. family). What happens to the system if you remove or replace an element?

Biological and ecological systems



James Lovelock

James Lovelock (1919-2022) was a British environmental researcher who introduced a new view of the Earth as a self-regulating system with his Gaia hypothesis. According to *Lovelock*, the Earth and its biosphere function like a living organism that keeps its physical and chemical conditions in a stable balance through feedback loops in order to enable life. Oceans and vegetation together regulate the CO² content and temperature of the atmosphere. *Lovelock* showed that interactions between living organisms and their inorganic environment ensure the complexity and stability of the Earth system. His approach emphasises the interdependence of life and the environment and makes it clear that disturbances in the ecological balance can have far-reaching consequences. This view influenced systems ecology and the understanding of global environmental change. However, the "respected" scientific community was largely critical of *Lovelock's* Gaia hypothesis.

Concept: *Lovelock's* concept for coping with complexity is based on the Gaia hypothesis, which describes the Earth as an interconnected, self-regulating system. Gaia maintains dynamic balance and stability through feedback loops and mutual adaptation between biological and geophysical processes.

Practical action: Systemic thinking and feedback for coping with complexity. Example: In climate research, *Lovelock's* concept is used to identify tipping points and model feedback effects such as the melting of ice sheets and the release of methane from permafrost soils in order to better understand global climate change and develop countermeasures at an early stage

Example: In sustainable urban planning, the Gaia principle is used to design urban ecosystems as self-regulating systems. Cities such as Copenhagen integrate green spaces and water areas that regulate the microclimate and air quality and ensure stability despite urban dynamics. Such approaches make it possible to recognise long-term interactions and unexpected side effects at an early stage. As a result, strategies can be developed that not only react to symptoms, but also address the causes of complex problems in the long term.²⁴

²⁴ **Reflection question:** What do you think about the Gaia hypothesis? Does it make sense to you that the Earth should be seen as a whole biological ecosystem?

Mini-exercise: Choose a place in your neighbourhood. Think about how it regulates itself ecologically or socially. What creates this balance?



Frederic Vester

Frederic Vester (1925-2003) German biochemist and pioneer of networked thinking, who made an important contribution to the understanding of complex systems with his work on sensitivity modelling. He is the author of the popular book: *Die Kunst, vernetzt zu denken*. According to *Vester*, networked thinking is crucial in order to understand the dynamics and interactions in ecological, economic and social systems and to manage them sustainably. He developed the sensitivity model, a computer-aided tool for dynamic simulation and decision support that makes complex relationships transparent through interaction matrices and control loops. The aim was to take a holistic view of the consequences of decisions and avoid unexpected side effects. *Vester* emphasised the need to take soft factors such as social and psychological influences into account. His approach promotes holistic management that develops sustainable solutions through feedback and self-regulation.

Concept: *Frederic Vester's* approach of networked thinking and sensitivity modelling makes it possible to understand and control complex systems in their dynamic interaction by integrating feedback loops and soft factors.

This promotes holistic and adaptive decision-making that minimises undesirable side effects and supports sustainable solutions.

Practical action: Example of corporate strategy: *Vester's* sensitivity model is used in corporate strategy to simulate complex market systems and analyse strategic decision-making options in terms of their impact on sales, customer behaviour, competitive dynamics and internal processes. By identifying sensitive variables and critical influencing factors using the influence matrix, companies can develop robust strategies that not only take into account short-term market changes, but also build long-term resilience to uncertainties and disruptive developments. The influence matrix can be used to identify important variables/levers in the system:

Active variables - good levers for exerting influence

Critical variables - caution can trigger a chain reaction

Reactive variables - no leverage, indicators for development

Inertial variables - negligible

Vester's sensitivity model thus supports fact-based, networked decision-making that helps companies to better understand complex interrelationships and develop sustainable strategies.²⁵

²⁵ **Reflection question:** In which area of your life are you currently lacking a networked view?

Mini-exercise: Choose a current problem or decision and outline the factors involved, which interactions have you overlooked so far and how do they change your view of possible solutions?



Lynn Margulis

Lynn Margulis (1938-2011), an American biologist whose research fundamentally changed the view of evolution and life on earth. With her endosymbiotic theory, she challenged the established idea of the development of complex cells and showed that co-operation and symbiosis are central driving forces of evolution. *Margulis* established that eukaryotic cells, i.e. those with a cell nucleus and organelles, emerged from the permanent uptake of formerly free-living bacteria. Thus, mitochondria and chloroplasts presumably originated from independent organisms that survived in a mutually beneficial community in larger cells. This finding emphasises the role of cooperation and symbiosis in evolution and complements the classic picture of Darwinism, which often focuses on competition.

Marguli's work made it clear that life is characterised by complex interactions and interdependencies and that organisms must not be understood in isolation, but as an integral part of communities and networks. In her view, life has conquered the earth not through struggle but through co-operation:

"Life did not take over the globe by combat, but by networking

The common interpretation of Darwin's theory of evolution, that only the strongest survive in competition, is therefore too one-sided. Instead, *Margulis* emphasised that evolutionary success arises from collaborative networks. *Margulis* was closely networked with *Lovelock* and together with him advocated the Gaia hypothesis.

Concept: *Margulis*'s approach to complexity shows that co-operation and symbiosis are central principles of evolution and ecological stability. Symbiotic relationships enable new capabilities and adaptations, creating complex systems through networking and integration. Adaptability and resilience are not only based on competition, but above all on co-operation. Ecosystems are dynamic networks of interdependence and co-operation that maintain stability and diversity through constant exchange.

Practical action: Co-operation to manage complexity. An example of successful co-operation in business is integrated project execution (IPA) in construction, which reflects the co-operative principle of Lynn Margulis' endosymbiosis theory. As in nature, where organisms develop new capabilities through symbiosis, all parties involved, such as civil engineers, architects, contractors, etc., work closely together to complete a project efficiently, cost-effectively and to a high standard.

Through early involvement, fair risk sharing, alignment of interests and the pursuit of a common goal, misunderstandings and costs are reduced. This collaboration promotes innovation, increases efficiency and reduces material waste, resulting in a successful and more sustainable construction project.²⁶

²⁶ **Reflection question:** What could you achieve if you worked more closely with others, not just cooperating, but also deep collaborating?

Mini-exercise: Reflect on an example of symbiotic collaboration in your everyday life. What makes it successful?



Fritjof Capra

The Austrian-American physicist *Fritjof Capra* (1939) initiated a paradigmatic change in scientific thinking with his interdisciplinary works. In his best-known book "The Tao of Physics", he combines the findings of modern physics with Eastern philosophy and shows that the world does not consist of isolated individual parts, but of interwoven processes and relationships. *Capra* emphasises that all life is based on networks that are interconnected through the constant exchange of matter and energy. This view led to a profound understanding of nature, science and society.

Through his work in systems theory and ecology, *Capra* made it clear that complex systems can only be understood if their dynamic interactions and feedback loops are taken into account. He shows that stability and change are not caused by linear causalities, but by circular processes in which cause and effect influence each other. *Capra's* thinking has significantly shaped systems ecology, organisational development and the understanding of global crises and offers integrative approaches for sustainable solutions. His online course "Capra Course" is based on his book "The Systems View of Life" and can be recommended without reservation.

Concept: *Capra's* concept for coping with complexity is based on a systemic view of the world that emphasises networks, dynamics and holism. He sees living systems as self-organising networks that are connected through constant exchange and feedback. *Capra* argues that stability and adaptability arise from the ability to react flexibly to change. He emphasises that systemic resilience arises from diversity and networking and that sustainable solutions are only possible if ecological, social and economic aspects are viewed as interlinked systems. *Capra* calls for a shift in thinking towards cycles and networks in order to master global challenges.

Practical action: Ecological networking in gardening and landscaping. Example: In permaculture, a garden is created in which plants, animals and microorganisms work together in symbiotic relationships. For example, nitrogen-fixing plants such as peas are planted next to vegetable plants such as tomatoes to promote growth. This networking of organisms strengthens the resilience and adaptability of the system by utilising natural processes such as nutrient cycles and water supply. The result is a sustainable, self-regulating ecosystem that reflects *Capra's* principles of networking and circulation

In addition, diverse habitats such as hedges, ponds or piles of dead wood provide refuges for numerous animal species, which in turn contribute to pest control. The targeted selection of site-appropriate plants also promotes biodiversity and strengthens the ecological balance. In the long term, this leads to lower maintenance requirements and greater stability against external influences such as weather extremes or pest infestations.²⁷

²⁷ **Reflection question:** What does it mean for you to think in a systemic context?

Mini-exercise: Think about how you can apply the understanding of systems in your everyday life.

Hard Systems, Soft Systems and Critical Systems



Russell Ackoff

Russell Ackoff (1919-2009) was an American systems theorist and management scientist. According to *Ackoff*, a system is not simply the sum of the behaviour of its parts, but rather the product of their interactions. He emphasised the emergent properties of systems that arise through the interaction and coordination of the parts. A well-known example that *Ackoff* often cited to illustrate this idea is that of the human being as a biological system. Humans can live, but none of their individual parts (such as the heart, lungs or brain) can do so alone. Humans can think, but the brain alone cannot think. Man can see, but the eyes alone cannot see. Man can write, but a hand alone cannot write.

Ackoff also used examples from other areas to illustrate his view of systems. For example, he viewed cars as technical systems. A car can drive, but the engine alone cannot drive. It requires the interaction and integration of various components, such as the engine, wheels, steering and drivetrain, to enable

the function of driving. *Russell Ackoff* was a pioneer in the field of systems theory and has made numerous contributions to management science and the study of complex systems.

Interactive Planning and the associated Idealised Design can be traced back to *Ackoff*. In interactive planning, the future is actively designed together with all those involved instead of just solving existing problems. Idealised Design, on the other hand, designs a future ideal system without restrictions and then plans backwards in order to realise it. Both methods emphasise holistic thinking and a proactive, future-oriented approach to complex systems.

Concept: *Russell Ackoff* believed that complex problems cannot be solved by breaking them down into individual components, but rather by recognising and shaping the interactions within the overall system. His approach was based on systemic thinking, interactive planning and idealised design, among other things.

Practical action: Optimisation of the overall system. Example: In the 1950s, Toyota was struggling with inefficient production processes, long lead times and frequent material shortages. Instead of focussing on isolated solutions to individual problems, such as selective process improvements or increasing stock levels, Toyota opted for a holistic approach. The company analysed the entire value chain and recognised that the problems were not isolated, but rather an expression of deeper systemic relationships.

From this systemic perspective, Toyota developed the just-in-time (JIT) principle, which sees production and logistics as an integrated, dynamic system. The aim was to minimise waste, synchronise the material flow and only produce what is actually needed. Particular emphasis was placed on continuous feedback and iterative improvements. All employees, from assembly line workers to managers, were actively involved in this learning and improvement process.²⁸

²⁸ **Reflection question:** Think about a problem that you have not been able to solve. What would be the ideal future state for it.

Mini-exercise: Sketch your personal future for the next five years. Now develop the steps from this future backwards to today.



Peter Checkland

Peter Checkland (1930) is a British systems scientist known for his work in the field of Soft Systems Methodology (SSM). He has made a significant contribution to the development of systemic thinking. *Checkland* emphasises the importance of looking at social systems and complex problems. His Soft Systems Methodology (SSM) is an approach to tackling such problems that takes into account human perspectives and the diversity of stakeholders. SSM aims to capture the complexity of social reality and address problems in a structured and systematic way. A central concept in *Checkland's* work is the consideration of systems in the context of their interactions with other systems. He points out that every system is part of a larger environment and is influenced by social, organisational and technological factors. These interactions between systems can lead to emergent properties and unpredictable outcomes.

Checkland therefore emphasises the need to view systems as part of a larger context and to understand the interactions between them. *Checkland's* approach is not only focussed on analysing and understanding systems, but also on deriving concrete action steps to solve problems. He emphasises the importance of dialogue and collaboration between different stakeholders in order to jointly develop innovative and sustainable solutions. *Peter Checkland's*

work has made a significant contribution to the further development of systemic thinking and the practical application of systems approaches.

Concept: *Peter Checkland's* approach to managing complexity is based on the Soft Systems Methodology (SSM), which addresses complex, unstructured problems in social systems. He points out the importance of the diverse perspectives of stakeholders and the dialogue between them. Instead of looking at problems in isolation, he sees them as part of a larger system whose interactions often produce unpredictable results. The focus is on systematically understanding complexity and developing solutions through collaboration.

Practical action: Reorganisation of information systems in the healthcare sector. Example: An interdisciplinary team consisting of doctors, nurses, administrative staff and patient representatives is working together to make patient care more efficient, particularly in the area of appointment allocation for outpatient treatment. Different perspectives were collected and jointly analysed in several workshops based on the Soft Systems Methodology (SSM). A central tool in this process was the so-called rich picture, a pictorial representation of the situation in which the actors involved, their interests and roles, as well as existing problems, information flows and areas of tension were visualised.

The rich picture served to visualise the complexity of the situation and create a common understanding of the initial situation. It facilitated dialogue between the participants and helped to identify misunderstandings at an early stage. On this basis, models were developed that showed various options for action. The focus was not only on the introduction of new IT systems, but also on the improvement of existing processes. The aim was to organise processes in such a way that they are more practicable and comprehensible for both patients and medical staff.²⁹

²⁹ **Reflection question:** In which situation would you be prepared not to look for a solution, but to let it develop together?

Mini-exercise: Choose a topic in which several perspectives are involved. Create a common picture (rich picture) with others, let the solution emerge through participation.



Mike C Jackson

Mike C. Jackson (1951) is a British systems scientist who has worked on the integration and critical analysis of various systems theory approaches. He is an important representative of Critical Systems Thinking (CST) and developed the Systems of Systems Methodology (SOSM) to deal with complexity. He proposes various systemic approaches for different degrees of complexity and system states. He particularly emphasises the importance of the human factor and its involvement in complex systems.

The SOSM distinguishes on the vertical axis (what kind of system it is) between simple and complex systems and on the horizontal axis (who the participants in the system are) between unity (i.e. a common understanding or opinion on a matter), pluralism (i.e. respected different understandings or opinions on a matter) and coercion (similar to pluralism, but here power can play a role in the system and exert coercion). This categorisation allows one of ten systemic methods to be selected to suit the respective situation.

Concept: *Mike C. Jackson's* concept for managing complexity is based on his Systems of Systems Methodology (SOSM), which proposes different systemic approaches depending on the degree of complexity and social dynamics. *Jackson's* approach makes it possible to select a suitable method to effectively manage complexity in different contexts by combining these dimensions and to develop solutions that take into account both the structure of the system and the social interactions of those involved.

Practical action: Political decision-making processes with the SOSM.

Example: In political decision-making processes, different parties and interest groups with sometimes contradictory interests come together. Such processes are tricky because they involve not only factual but also social, cultural and power-related dynamics. The Systems of Systems Methodology (SOSM) can provide valuable assistance in such situations. Its main benefit lies in systematically assessing which systemic method, such as SSM, CST or VSM, is most suitable for the situation in question. The SOSM acts as a kind of overarching orientation aid or "meta-model" that enables the selection of suitable methods. It helps to recognise whether, for example, the aim is to create consensus (uniformity) or whether a pluralistic approach is required in which different points of view should be given equal consideration. This assessment is crucial as it influences how complexity, conflict and power relations are dealt with

In authoritarian political systems in which coercion and hierarchical control dominate, SOSM shows that methods are needed that both critically reflect power relations and incorporate the reactions and needs of the population. In such contexts, Critical Systems Thinking (CST), for example, can be useful, as it poses specific questions about power, justice and marginalisation. In more democratic processes, where it is more important to integrate different perspectives and develop viable solutions, the Soft Systems Methodology (SSM) can be helpful. It makes it possible to capture the often contradictory perspectives of those involved and integrate them into the decision-making process through dialogue. When it comes to the organisational controllability and adaptability of political systems, the Viable Systems Model (VSM) can also provide orientation. Overall, the SOSM allows a well-founded, situation-specific selection of systemic methods.³⁰

³⁰ **Reflection question:** Which different system methods do you need in order to adequately grasp the complexity of your current challenge?

Mini-exercise: Choose a specific challenge, analyse it with SOSM in terms of its complexity and consciously choose a suitable method.

Management



Peter Drucker

The Austrian *Peter Drucker* (1909-2005) is considered one of the most influential pioneers of modern management theory. He is best known for his groundbreaking contributions to organisational theory and for the concept of "Management by Objectives" (MBO), which is still used as a fundamental management method in many companies today. *Drucker* emphasised that managers should set clear objectives and measure the performance of employees against these objectives in order to increase the efficiency and effectiveness of organisations. He also emphasised the importance of marketing and innovation as key drivers of corporate success.

Drucker also developed the concept of the knowledge worker to emphasise the growing importance of knowledge and expertise in modern organisations. He recognised that knowledge is the key to the competitiveness of companies and that the handling of knowledge and the promotion of knowledge workers play a central role. In view of the increasing complexity in organisations, *Drucker* recommended simplifying relationships within companies. This could be achieved by reducing complexity in structures and processes as well as through clarity and focussing on the essential tasks and goals. *Drucker* states that this not only promotes efficiency, but also

strengthens the understanding and motivation of employees. After all, *Drucker* was convinced that people are a company's most valuable asset and that valuing and promoting employees is a key prerequisite for a company's long-term success.

Concept: *Peter Drucker's* concept for managing complexity is based on simplification, clear objectives and decentralisation. He recommended simplifying structures and processes, shifting responsibility to lower levels and setting clear objectives (management by objectives). He also emphasised the importance of knowledge as the most valuable resource and saw continuous innovation and a long-term perspective as the key to successfully overcoming complexity.

Practical action: Introducing and operating knowledge management in the organisation. According to Peter Drucker, this means systematically capturing, sharing and productively utilising knowledge, always with a view to the company's strategic goals. A practical example is the establishment of a company-wide knowledge management platform on which employees can exchange best practices, experiences and solutions to problems. This not only promotes the exchange of knowledge, but also strengthens cross-departmental collaboration and the capacity for innovation.

Attention should be paid to user-friendly technical implementation that can be seamlessly integrated into existing work processes. Furthermore, continuous learning should be institutionalised through regular workshops, training and mentoring programmes. Experienced employees can pass on their project or company knowledge to younger or new colleagues in a targeted manner. This not only improves the transfer of knowledge, but also strengthens networking between different hierarchical levels and specialist departments. For knowledge management to be effective in the long term, it requires strategic anchoring and a supportive corporate culture. Managers play a key role here by exemplifying and specifically promoting active knowledge behaviour.³¹

³¹ **Reflection question:** How could you focus your attention on the essentials in order to make more effective decisions?

Mini-exercise: Identify a current decision that you need to make. Consciously set yourself a goal that allows you to focus on the essentials and minimise the unimportant details.



Hans Ulrich

The Swiss *Hans Ulrich* (1919-1997) was the first person in Europe to establish a holistic management theory based on systems theory and cybernetics at a European business university. The aim was to enable effective management of increasing complexity. His work also gave rise to the St. Gallen Management Model. The Swiss school of management shaped by *Ulrich* was strongly influenced by British cybernetics, in particular by *Stafford Beer* and his Viable System Model. This influence can still be seen today in *Ulrich's* students such as *Fredmund Malik*, *Peter Gomez* or their students such as *Martin Pfiffner*. *Ulrich* also coined a distinction between complication and complexity that is widely used today. He defined complexity as follows:

"Complexity is the ability of a system to assume a large number of different states in a short period of time."

This makes the difference clear: complicated systems consist of many components whose interaction can be understood and predicted. Complex systems, on the other hand, change quickly and unpredictably, which makes them considerably more difficult to control. *Ulrich* recognised that dealing with such systems requires a new type of management, beyond Taylorism and mechanistic planning logic. He argued in favour of systemic management

based on clear structures, sensible decision-making rules, processes, feedback loops, continuous improvement and a high degree of adaptability.

Concept: *Hans Ulrich's* concept for dealing with complexity is based on a holistic approach based on systems theory and cybernetics. He distinguishes between complicated (structure of a system) and complex (temporal variability and unpredictable behaviour). Ulrich proposes managing complex systems through clear structures, processes and decision rules that are continuously improved and adapted to changes in order to deal effectively with uncertainty and complexity.

Practical action: A holistic view of the management of companies. Example: Through the influence of *Hans Ulrich* and the system-orientated business management theory he coined, many companies began to no longer view their internal structures and processes in isolation, but as parts of an overall system. Instead of purely functional management, in which production, sales and finance, for example, were optimised separately from each other, an understanding of the mutual dependencies and feedback effects between the company divisions came to the fore.

Companies began to develop scenarios in which they anticipated interactions and aligned strategies to be able to react flexibly to different developments. For example, a new market strategy was no longer viewed in isolation, but simultaneously with effects on the supply chain, the personnel structure, the corporate culture and the IT system.³²

³² **Reflection question:** Reconsider the difference between complicated and complex. Why is the distinction relevant?

Mini-exercise: Outline a decision-making situation in your environment. Are there clear structures, processes and rules?



Fredmund Malik

Fredmund Malik (1944) is an Austrian economist and management cyberneticist. His university teacher was *Hans Ulrich*, who brought systems science to St. Gallen and founded the St. Gallen Management Model. *Peter Drucker*, *Stafford Beer* and *Frederick Vester*, among others, also had a significant influence on him. He is the author of many management books, some of which have a broad popular readership, such as his book "Managing, Performing, Living: Effective Management for a New World" in which he describes how the craft of the manager and dealing with complexity can be learnt. He defines six principles for effective management:

1. Results-orientation: The focus is on concrete results and the benefits for the company.
2. Contribution to the whole: Every activity should have a recognisable value for the organisation or society.
3. Focus on the few: Effective managers prioritise and avoid getting bogged down.

4. Utilise strengths: Instead of working on weaknesses, individual and organisational strengths should be used in a targeted manner.
5. Trust: A culture of trust is essential for sustainable success.
6. Positive and constructive attitude: A solution-orientated mindset is crucial for effective management.

These principles are central to *Malik's* management approach, which aims to make organisations future-proof.

Concept: *Fredmund Malik's* concept for dealing with complexity is based on a cybernetic management approach that views companies as dynamic, self-regulating systems. Instead of controlling them centrally, he favours systemic thinking, clear structures and adaptive decision-making mechanisms. As complexity cannot be completely controlled, *Malik* advocates focussing on the essentials, as is made clear in his six management principles.

Practical action: Introduction of systemic management in the company. Example: Companies are to be understood as complex, dynamic systems in which various elements are interlinked and interdependent. Systemic management is the management of many, it recognises complexity and promotes thinking in terms of interrelationships rather than isolated individual parts. Managers are required to keep an eye on the entire system, make decisions based on long-term goals and sustainably increase the functional effectiveness of the organisation.

One of *Fredmund Malik's* central concepts is the *Malik* Management System (MMS). It provides a methodologically sound basis for analysing, managing and optimising organisations. It trains managers to navigate successfully through complex and unstable environments with the help of system-orientated principles.³³

³³ **Reflection question:** Which elements in your organisation need to be better balanced instead of optimised individually?

Mini-exercise: List 5 central elements of your organisation. Connect the elements that are in tension with each other (e.g. quality ↔ speed).



Ralph D. Stacey

The British organisational and management researcher *Ralph D. Stacey* (1942-2021) is considered a pioneer when it comes to combining approaches from the natural sciences to complexity with the understanding of organisations and management and using them fruitfully. *Stacey's* work was influenced by chaos theory and complex adaptive systems. He developed the *Stacey matrix*. This was developed to classify the dynamics and complexity of decision-making situations in organisations. It was not developed to derive generalised methods, but to make thinking and acting more conscious.

However, due to the incorrect use of the *Stacey matrix*, he later rejected its use and developed the "Theory of Complex Responsive Processes of Relating" together with colleagues from his faculty at the university of hertfordshire. The focus here is on emphasising the role of people in organisations and their dynamic interactions that lead to emergent behaviours.

This approach takes into account the non-linear and non-deterministic aspects of organisations and emphasises the importance of relationships and interactions between the actors. The "Theory of Complex Responsive Processes of Relating" builds on the understanding that organisations are complex social systems in which relationships, interactions and behaviours continuously develop and adapt. It assumes that the behaviour of organisations and their members is not predictable or controllable, but emergent.

This means that the individual actions and decisions of people in the organisation are interconnected and influence each other, resulting in a dynamic that cannot simply be predetermined. The theory also emphasises the importance of reflexivity and mutual influence in relationships within the organisation. It suggests that the perceptions, interpretations and meanings that people attribute to situations and events shape their interactions and actions. As a result, the organisation and its members are in a constant process of reacting, adapting and reinterpreting.

Concept: *Ralph D. Stacey* sees organisations as complex social systems in which change arises through interaction rather than through planning and control. His "Theory of Complex Responsive Processes of Relating" emphasises that innovation and change emerge from everyday dialogue, conflict and collective reflection. Leadership therefore means embracing uncertainty and creating spaces for social interaction rather than imposing rigid structures.

Practical action: Leadership as moderation of relationships. Example: In *Stacey's* understanding, leadership means consciously shaping social interactions. Managers create spaces for dialogue, reflection and joint learning in which different perspectives meet and are negotiated together. Mistakes, conflicts and uncertainties are not seen as disruptions, but as opportunities for further development and innovation.

Decisions are not made in isolation at the top, but through the interaction of many participants, making organisations more adaptable and resilient to complexity.³⁴

³⁴ **Reflection question:** Where do you need less planning and more presence in the here and now in order to lead or be led in a meaningful way?

Mini-exercise: Choose a current decision-making situation and place it in the Stacey matrix.

Systemic counselling and systems practice



Fritz B. Simon

Fritz B. Simon (1953) is a German physician, psychiatrist, systems theorist and organisational consultant. He is regarded as one of the central figures of the systemic movement in the German-speaking world and has made a significant contribution to the dissemination and further development of systemic thinking in psychotherapy, counselling and, in particular, in organisations. His scientific roots lie in systemic therapy. He was influenced early on by influential thinkers such as *Paul Watzlawick*, *Heinz von Foerster*, *Humberto Maturana* and *Niklas Luhmann*. He combines these influences in his work in his own unique way and uses them to develop a specific system-theoretical understanding of human communication, social systems and organisational dynamics.

Simon works intensively on the application of systems theory concepts to leadership, management, decision-making and change processes in organisations. He advocates an understanding of organisations as living, self-organising systems whose dynamics cannot be controlled linearly, but can only be understood and influenced. Through his work, *Fritz B. Simon* has had a lasting influence on the development of systemic theory and practice, not only in psychotherapy, but also in organisational consulting, coaching and leadership development.

Concept: *Fritz B. Simon's* concept for dealing with complexity is based on a constructivist systems theory approach in which organisations are described as autopoietic systems that exist and sustain themselves through communication. Decisions generate new decisions, creating a dynamic network that cannot be controlled centrally. In this context, leadership means providing offers of meaning that enable connectivity and provide orientation. Complexity cannot be reduced, it can only be made productive through structure, role clarification and communication.

Practical action: Introduction of systemic thinking in organisations. Example: Companies are seen as decision-making systems whose communication can be specifically analysed and influenced. Managers should not try to control everything, but establish spaces for self-organisation. The central tools here are systemic constellations, the analysis of organisational paradoxes and the conscious handling of blind spots in social systems.

Decisions should not be simplified, but understood and organised in their complex interdependence. Above all, leadership means creating the conditions for good decisions. This is achieved through clear roles, transparent communication channels and the promotion of reflection. The aim is to make organisations robust in the face of unwanted change, not through rigid control, but through the ability to learn and the willingness to be irritated in order to make productive use of this.³⁵

³⁵ **Reflection question:** What would have to change in your team for the problem to stop making sense?

Mini-exercise: Identify a paradox in your day-to-day work and think about who benefits from the fact that it remains unsolvable.



Patrick Hoverstadt

Patrick Hoverstadt is a British consultant and author who specialises in the application of systemic approaches to the analysis and design of organisations. He has been particularly influenced by the work of *Gregory Bateson* and *Stafford Beer*. His expertise lies in the areas of strategy, organisational analysis and design and change management. *Hoverstadt* has developed his own systemic approaches such as *Patterns of Strategy* and *Mosaic Transformation*. His book "The Systems Grammar" focusses on the heuristic systems laws of systems thinking and their application. He represents the British multi-method approach to systems thinking, similar to *Mike C. Jackson*, and is a strong advocate of systems practice, i.e. the practical application of often theory-orientated systemic concepts.

Concept: In dealing with complexity, *Patrick Hoverstadt* assumes that organisations should be viewed as viable, self-regulating systems. He uses the Viable System Model (VSM) to analyse and design organisations and promotes dynamic, adaptable strategies with *Patterns of Strategy*. With *Mosaic Transformation*, he supports step-by-step, modular change processes. His multi-method approach combines various systemic methods to find practical solutions to complex organisational challenges.

Practical action: Strategic corporate planning. Example: In the area of strategic planning, the "Patterns of Strategy" concept co-developed by *Hoverstadt* offers organisations innovative methods for planning and adapting

their strategic direction. By identifying and applying specific patterns, companies can react to changes in the market environment and strengthen their position.

One example of a pattern of strategy is the "first mover" strategy. Companies that seize a new market opportunity at an early stage can gain a competitive advantage through innovation and branding. Either by being operationally fast, which has more of a short-term effect. Or by being innovative and fast, which has a longer-term effect. With regard to the possibilities of using artificial intelligence in the context of employee efficiency in companies, this is an exciting strategy that will be a focus of attention in the coming years.³⁶

³⁶ **Reflection question:** What strategic patterns or heuristics (system laws) are you aware of?
Mini-exercise: Sketch a planned change and describe which strategic pattern you recognise in it.

Summary

Natural sciences: *Henri Poincaré* emphasised the sensitivity of a system to its initial conditions as a central principle for explaining complexity. Even the smallest changes can lead to unpredictable results. *Edward Lorenz* showed that although complex systems react sensitively to minimal changes, they also exhibit patterns that make their dynamics easier to understand. *Benoît Mandelbrot* considered self-similarity and fractality to be fundamental structures of nature that help to organise complexity. The natural sciences describe fundamental properties of complex systems, including non-linearity and sensitivity to initial conditions. In addition, they have shown that patterns exist in both complex and chaotic systems that reveal an inner structure despite apparent disorder. Nature uses fractality as one of several mechanisms to organise complexity efficiently.

General systems theory: *Ludwig von Bertalanffy* and *Kenneth Boulding* made significant contributions to systemic thinking by transcending the boundaries of individual disciplines and searching for universal principles that describe complex systems. *Bertalanffy* emphasised the dynamics of open systems with his General Systems Theory, which influenced Nobel Prize winner for Chemistry *Ilya Prigogine*, among others. *Boulding* recognised the importance of networks and sustainable interactions. Parallels to Boulding's work, particularly with regard to an ecological approach, can be found in the work of *Fritjof Capra*, *Frederick Vester* and *Donella Meadows*. Both *Bertalanffy* and *Boulding* emphasised the need for interdisciplinary approaches in order to overcome complex challenges, thereby laying an important foundation for understanding complexity.

Early cybernetics: *Norbert Wiener* described the importance of feedback for the control of technical, biological and social systems, thereby laying the foundation for cybernetics. *Warren McCulloch* developed the *McCulloch-Pitts neuron*, a model for artificial neuronal networks, and made it clear that information processing takes place most effectively where the most relevant information is available. *Ross Ashby* formulated the "Law of Requisite Variety" as a fundamental principle of system control. *Gregory Bateson* regarded patterns and relationships as central elements of complex systems and showed that communication and learning are controlled by interactions and feedback. *Niklas Luhmann* also emphasised that the consideration of relationships within a system, and not just the individual parts, is crucial. These concepts still shape our understanding of control, self-organisation and

information processing in natural and artificial systems today. They make it clear that complexity must be countered by a deep understanding of patterns, feedback and adaptation mechanisms.

Late cybernetics: Late cybernetics, characterised by *Heinz von Foerster*, *Stafford Beer* and *Humberto Maturana*, expanded the understanding of complex systems. *Von Foerster* developed second-order cybernetics, which includes the observer as part of the system and emphasises the observer's influence on the system. *Beer*, influenced by *Ashby*, introduced the Viable System Model (VSM), which describes organisations as self-organising, adaptive systems. With Syntegration, he developed a method for equal, networked decision-making. *Maturana* coined the concept of autopoiesis, which describes the ability of systems to create and maintain themselves, and developed the concept of structural coupling, which explains the reciprocal influence of autopoietic systems and their environment. Late cybernetics focused on the role of the observer, self-organising and self-creating processes.

System Dynamics: *Jay W. Forrester* developed System Dynamics as a mathematical quantitative modelling tool to analyse feedback loops and time delays in systems. His findings are used in business and politics. *Donella Meadows* deepened this knowledge and, with her concept of leverage points, showed how targeted interventions in systems can have a major impact. Like *Poincaré* and *Lorenz*, she also focussed on the sensitivity of systems. *Peter Senge* transferred systems thinking to companies and organisations. His vision of the learning organisation emphasises the importance of reflection, common goals and continuous adaptation. He uses systemic archetypes to help recognise and improve patterns in decision-making processes. Together, these approaches emphasise that the world is interconnected. Those seeking change must look beyond isolated measures and understand the interplay of structures, dynamics and feedback mechanisms.

Complexity theory: With his theory of dissipative structures, *Ilya Prigogine* showed that order can arise in open systems through the continuous exchange of energy, matter or information. *Holland* as one of the founders of Complex Adaptive Systems approach shows that many autonomous agents interact without central control and organise themselves. Influenced by *McCulloch* and *Ashby*, *Stuart Kauffman* researched self-organisation and the dynamics between order and chaos. His NK model describes how systems evolve through internal interactions. *Dave Snowden* used the Cynefin framework to explain complex decision-making processes. In uncertain systems, he favours experimentation and iterative learning. *Yaneer Bar-Yam* analysed the interdependencies in complex systems and developed methods

for multi-scale analysis. His findings help to overcome global challenges, for example through adaptive strategies in the financial sector that use algorithms to compensate for market volatility. Together, these approaches show that complex systems are dynamic and networked. Dealing with them requires an understanding of self-organisation, feedback effects and emergent structures.

Psychology, sociology and philosophy: *Kurt Lewin*, *Niklas Luhmann* and *Klaus Mainzer* made key contributions to the understanding of complex social systems. *Lewin* viewed social systems as dynamic fields of influencing forces and developed models such as force field analysis and the three-phase model of change. *Luhmann*, inspired by *Maturana*, understood social systems as autopoietic, self-referential units that operate through communication, whereby selection contributes to the reduction of complexity. *Mainzer* analysed complexity as non-linear interactions and emphasised early warning systems and AI-supported simulations to stabilise chaotic systems. All three approaches offer valuable insights for the management of complex structures.

Biological and ecological systems: *James Lovelock's* Gaia hypothesis describes the earth as a self-regulating system that remains stable through feedback loops. *Frederic Vester* developed sensitivity modelling to promote networked thinking and systemic decision-making. *Lynn Margulis* showed with her endosymbiotic theory that co-operation and symbiosis are central driving forces of evolution. *Fritjof Capra* combines modern physics with systems theory and Eastern philosophy and emphasises the importance of networks and circular processes. These concepts find practical application in areas such as climate research, corporate strategy, construction and permaculture in order to develop resilient solutions.

Hard Systems, Soft Systems and Critical Systems: *Russ Ackoff* emphasised the importance of interactions within a system and advocated holistic optimisation. *Peter Checkland* developed the Soft Systems Methodology (SSM), which takes particular account of social systems and the diversity of stakeholder perspectives in order to design sustainable solutions. *Mike C. Jackson's* Systems of Systems Methodology (SOSM) enables a differentiated analysis of complex systems based on structural and social factors in order to select suitable methods for different contexts. All three approaches share the realisation that isolated problem solving is inadequate and that a systemic, interactive and adaptable approach is required instead.

Management: *Peter Drucker* focussed on simplification, clear objectives (management by objectives) and the importance of knowledge workers for the success of the company. *Hans Ulrich*, influenced by *Bertalanffy* and *Beer*, developed the St. Gallen management model. He

distinguished between complexity and intricacy and called for a systems approach to the continuous adaptation of organisations. *Fredmund Malik* built on this and viewed management as a cybernetic system in which focus, feedback mechanisms and trust are crucial. *Ralph D. Stacey*, on the other hand, emphasised the emergent properties of organisations and developed the theory of "Complex Responsive Processes of Relating", which focuses on dynamic interactions and social processes as drivers of change and innovation. Together, their approaches show that successful leadership is not achieved through rigid control, but through adaptive, systemic and people-centred methods.

Systemic consulting and systems practice: *Fritz B. Simon* describes organisations as autopoietic systems that exist and organise themselves through communication. Complexity should not be reduced, but utilised through role clarification and targeted communication. *Patrick Hoverstadt* uses the Viable System Model (VSM) to analyse organisations and develops adaptive strategies with "Patterns of Strategy". His multi-method approach combines various systemic methods for practical solutions. Both actors show that effective change in complex systems can be achieved by understanding interrelationships and targeted interventions.

Critical reflection

The variety of theories on dealing with complexity shows an impressive theoretical spectrum on the one hand, but reveals areas of tension in terms of practical application on the other.

The quote

For every complex problem there is a simple solution, and it is wrong,

which is attributed to Umberto Eco, sums it up: the desire for simple solutions to complicated and complex challenges often remains unfulfilled. Many models provide complex analyses, but remain abstract or difficult to communicate in practice. Terms such as self-organisation or emergence sound inspiring, but run the risk of remaining vague. Complexity is often recognised rhetorically without this leading to changes in decision-making processes. The reflexive demands on management and organisations are high, often higher than can actually be realised.

Another critical point is the implicit normativity of many approaches. Self-organisation is often presented as an ideal without reflecting on the social, political or cultural preconditions. This overlooks the fact that even complex systems can reproduce power relations and exclusions. In addition, the dependence on observers often remains theoretical in practice. The demand for a diversity of perspectives and context sensitivity is understandable, but is rarely implemented consistently. Methodologically, it remains unclear how one can work productively with contradictory perspectives without falling into arbitrariness or indecisiveness. It is questionable whether the breadth of the concepts can do justice to their depth or whether they will remain in a niche, as a sophisticated school of thought for a few insiders.

Despite their analytical depth and interdisciplinary richness, many approaches to dealing with complexity remain difficult to apply in practice. The challenge is to build viable bridges between theoretical aspirations and organisational reality without trivialising or mystifying complexity. Dynamic contexts in particular show how demanding it is to translate theoretical concepts into concrete action strategies. This makes it all the more important to dovetail theory development and practical testing in order to realise the potential of complexity theory approaches.

Dealing with complexity in just a few steps

You can't deal with complexity in just a few steps, that's an oversimplification. Nevertheless, I am writing this here because all the theory surrounding systems and complexity is sometimes simply too much. So if you are looking for a really short framework for action, you will find it here.

1. Recognising and understanding complexity: The first step in dealing with complexity is to understand the nature and structure of the system. This involves identifying elements, relationships, feedback, patterns and non-linear interactions as described in cybernetics and complexity theory, among others. It is important to recognise the dynamics and sensitivity to initial conditions as described by *Poincaré* and *Lorenz*. The analysis of self-similarity and fractality, as emphasised by *Mandelbrot* and *Beer*, helps to gain a deeper insight into the underlying order.

2. Incorporate interdisciplinary perspectives: Dealing with complex systems requires an interdisciplinary approach that integrates different perspectives and disciplines. *Bertalanffy* and *Boulding* emphasised the need to overcome boundaries between disciplines in order to develop universal principles. In practice, this means considering social, ecological and economic dimensions alongside technical aspects, for example, as found in the work of *Capra*, *Lovelock* and *Meadows*. It is crucial to include different perspectives in order to grasp the complexity of problems.

3. Promoting self-organisation and adaptability: In order to deal with the unpredictability of complex systems, it is important to promote self-organisation and adaptability. Cybernetics and the theory of dissipative structures, as formulated by *Maturana* and *Prigogine*, show that systems can remain stable through their ability to self-regulate and adapt. This can be implemented in organisations using *Beer's* Viable System Model (VSM) or the practice-oriented methods and approaches of *Hoverstadt*, which enable self-organisation and continuous learning.

4. Use systemic decision-making and feedback loops: Decisions in complex systems should be based on systemic negative feedback loops, as emphasised by *Wiener* or *Forrester*. This requires considering not only short-term effects, but also long-term effects and undesirable side effects. The application of concepts such as *Meadows'* leverage points and the

experimentation and learning orientation in *Snowden's* Cynefin framework can help to make targeted and adaptive interventions.

5. Integration of sustainability and resilience: The final step in this brief framework for action is to integrate sustainability and resilience into decision-making processes. This means designing systems in such a way that they not only react to change, but can also regenerate and adapt themselves. Concepts such as *Lovelock's* Gaia hypothesis and *Vester's* sensitivity modelling show how important it is to include ecological and social systems in their decision-making.

Brief overview of actors

Natural sciences



Henri Poincaré

Chaos theory

Non-linearity

Weak Signals



Edward N. Lorenz

Butterfly effect

Lorenz attractor (pattern/order in chaos)



Benoît Mandelbrot

Mandelbrot set

Fractals

Repeating patterns and self-similarity

General system theory



Ludwig von Bertalanffy

General systems theory

Common language and understanding

Living systems are open systems



Kenneth Boulding

Cross-system

Network of systems and interactions

Systemic sustainability

Early cybernetics



Norbert Wiener

Control/ regulation in technical, biological and social systems

Black box principles

Feedback



Warren McCulloch

Redundancy of Potential Command

Neural networks

Decentralised control



Ross Ashby

Ashby's Law: Law of Requisite Variety "Only Variety can absorb Variety"

Variety management

Brain as a model for self-organisation, homeostasis and ultrastability



Gregory Bateson

Double bind theory

Patterns that connect (don't focus on the elements, but on the connections and patterns)

Late cybernetics



Heinz von Foerster

2nd order cybernetics: Observation of observation

Ethical imperative: "Always act in a way that increases the number of choices!"



Stafford Beer

Viable System Model

Syntegration



Humberto Maturana

Autopoiesis (self-generation)

Structural coupling (mutual adaptation of system and environment)

System Dynamics



Jay Wright Forrester

System Dynamics

Quantitative flow charts

Interdependence



Donella Meadows

Sustainability

Leverage points



Peter Senge

Systemic archetypes (patterns)

Learning organisation

Systems Thinking

Complexity theory



Ilya Prigogine

Self-organisation/dissipative structures (order is created through the exchange of energy between the open system and the environment)

Open systems



John H. Holland

Complex Adaptive Systems (CAS)

Emergence



Stuart Kaufmann

Complex Adaptive Systems (CAS)

Edge of Chaos

NK model (fitness landscapes)



David Snowden

Cynefin Framework

Narrative



Yaneer Bar Yam

Multi-scale analyses

Decentralised decision-making structures

Networks

Psychology, sociology and philosophy



Kurt Lewin

Field theory

Force field analysis

3 phase model



Niklas Luhmann

Luhmann's systems theory

Communication constitutes systems

Facing complexity through selection



Klaus Mainzer

Sensitivity to initial conditions.

Early warning systems

Negative feedback

Biological and ecological systems

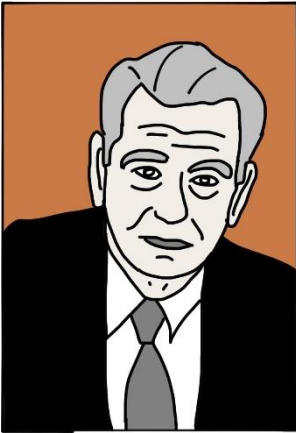


James Lovelock

Gaia hypothesis

Feedback

Interaction between life and inorganic matter



Frederic Vester

Sensitivity model

Interaction

Feedback



Lynn Margulis

Endosymbiotic theory

Cooperation and symbiosis in networks



Fritjof Capra

Combining physics and Eastern philosophy

Life is based on networks

Interaction and feedback

Hard Systems, Soft Systems and Critical Systems



Russell Ackoff

A system is a product of its interactions

Interactive Planning

Idealisation Design



Peter Checkland

Soft Systems Methodology (SSM)

Rich Picture

Interaction with other systems



Mike C Jackson

Critical Systems Thinking

Systems of Systems Methodology (SOSM)

Management



Peter Drucker

Management by Objective

Marketing and innovation

Knowledge worker

Simplification of structures



Hans Ulrich

St. Gallen Management Model

Complicated and complex



Fredmund Malik

Management is a craft

Dealing with complexity can be learnt



Ralph D. Stacey

Stacey matrix

Theory of Complex Responsive Processes of
Relating

Systemic counselling and systems practice



Fritz B. Simon

Systemic therapy and counselling

Systemic organisational consulting

Paradoxes



Patrick Hoverstadt

Patterns of Strategy

The Grammar of System

Systems Practice

Recommended reading

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SCiO - System and Complexity in Organisation. www.systemspractice.org

<https://www.santafe.edu/>

<https://www.capracourse.net/>

Cybernetic Society <https://cybsoc.org>

<https://metaphorum.org>

<https://www.simon-weber.de>

New England Complex System Institute <https://necsi.edu>

Complexity Science Hub Vienna <https://csh.ac.at>

Glossary

Adaptivity: The ability of a system to adapt flexibly to changes in the environment.

Archetype (systemic): Recurring systemic pattern of cause-and-effect chains that occurs in many organisations or systems. Term coined by Peter Senge.

Autopoiesis: Maturana & Varela's concept: A system maintains itself by continuously reproducing its own elements and structures.

CAS - Complex Adaptive System: System with many interacting, autonomous components (agents) that is capable of learning and self-organising.

Chaos theory: Research into systems with deterministic but unpredictable behaviour in which small changes can have large effects.

Dissipative structures: Concept coined by Ilya Prigogine: Ordered structures that arise in open systems far from equilibrium.

Edge of chaos: Stuart Kauffman's term: transition zone between order and chaos in which complex systems are particularly creative and adaptable.

Emergence: Unexpected new properties of a system that cannot be derived from the individual components, but arise from their interactions.

Feedback:

Feedback of system information. Negative feedback stabilises, positive feedback reinforces developments.

Fractals: Concept introduced by Benoît Mandelbrot: Structures that resemble themselves, regardless of the level of observation. Often found in nature (e.g. leaves, coastlines).

Leverage points: Term coined by Donella Meadows: Points in a system where small changes can have a big impact.

Complexity: Large number of dynamically linked elements with non-linear relationships whose behaviour is difficult to predict.

Cybernetics: The science of control and communication in machines, living beings and organisations.

Law of Requisite Variety: Law formulated by Ashby: A system can only react adequately if its control variety corresponds to the environmental variety.

Learning organisation: An organisation that continuously improves its structures through feedback, reflection and joint learning.

Pattern recognition: The process of recognising recurring structures or dynamics in a complex system.

Path dependency: System behaviour that is shaped by previous decisions and structures and limits change.

Self-organisation: Order arises spontaneously in the system through internal interactions, without external control.

Soft Systems Methodology (SSM): Approach by Peter Checkland: Method for solving complex, "soft" problems by incorporating subjective perspectives.

SOSM - System of Systems Methodology: Approach developed by Mike C. Jackson for integrating various systemic methodologies in particularly complex contexts.

System: A set of elements that is connected via relationships, has a function and is differentiated from the environment.

System Dynamics: Modelling approach developed by Jay W. Forrester for complex systems, using flow charts, feedback loops and simulation.

System boundary: Conscious setting of a system's boundaries from its environment. Determines the focus of the analysis.

Systemic counselling: Practical approach with a neutral attitude that reflects and changes interactions, patterns and communication within systems.

Viable System Model (VSM): Model by Stafford Beer for describing viable (adaptable) organisations with recursive control structures.

Weak signals: Early, subtle signs of upcoming changes that are highly significant for forecasts or strategies in complex systems.

Second order (cybernetics): Refers to the inclusion of the observer in the system. Epistemological extension of classical cybernetics.

List of abbreviations

Abbrevia- tion	Meaning
AI	Artificial Intelligence
B	Relationships (between elements)
CAS	Complex Adaptive Systems
CST	Critical Systems Thinking
E	Elements
C	Complexity (in the formula $C = (E \times B \times V) \times (t)$)
MIT	Massachusetts Institute of Technology
NK model	Fitness landscapes (N = elements, K = link density)
SFI	Santa Fe Institute
SSM	Soft Systems Methodology
SOSM	System of Systems Methodology
t	Temporal change
V	Behaviour (of the relationships)
Ve	Environment variety (variety of the environment)
Vc	Controlling variety (variety of control)
VSM	Viable System Model

VUCA Volatility, Uncertainty, Complexity, Ambiguity (volatile, uncertain, complex, ambiguous)

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"Learning never stops"