Beyond Darwin - the general evolutionary theory as unification of biological and cultural evolution

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Abstract: The general evolutionary theory can be seen as a comprehensive generalization and extension of Darwin's theory. The basic idea is to consider not only the evolution of genetic information - as Darwin did - but also the evolution of very general information. It shows that evolution is characterized by the fact that new types of information have developed in leaps and bounds, each with new storage technologies, new duplication technologies and new processing technologies. This unified concept of evolution makes it possible, among other things, to 1) achieve a unified view of biological and cultural evolution; 2) find a natural periodization of the evolution from the formation of the earth until today; and 3) understand the exponential acceleration of evolution through the emergence of targeted variation mechanisms.

1. So why is the world the way it is?

The central aim of Big History (Christian, 2004; Spier, 1996) is to understand the essential mechanisms of evolution that have led to the world being the way it is. The general evolutionary theory (Glötzl, 2023b, 2023a) tries to give an answer for the time from the formation of the earth to the present and the future.

Charles Darwin (Darwin, 1859) has already explained much of this: namely the biological evolution, i. e. how and why the different species have evolved from single-celled organisms to animals and finally to humans, but he was not able to explain everything. In particular, he did not provide answers to cultural evolution, such as the following questions:

- Why, for example, did hearing, speaking, writing, printing and computer technology develop in this order?
- Why did the economy evolve from a barter economy to an economy based on the division of labor and further on to a market economy with money and investment?
- Why has money evolved from commodity money to coin money to paper money and to electronic money?
- Why can animals imitate and humans learn and teach?
- Why and when did the different cooperation mechanisms develop (group coop., direct coop., debt coop., indirect coop., cooperation via norms?
- Why did everything develop in exactly this order?

But more importantly,

- Why is everything evolving faster and faster?
- Where is the journey of evolution heading in the future**?**
- Are we heading for a singular point?

All these and many other questions are questions of cultural evolution (Boyd & Richerson, 2005). The most prominent discussions explaining cultural evolution relate to universal Darwinism (Campbell, 1965; Cziko, 1997), dual inheritance theory (E. O. Wilson, 1999), and memetics (Blackmore, 1999; Dawkins, 1989). There is much debate about the extent to which there are parallels between biological and cultural evolution (Grinin et al., 2013), and how unification can be achieved (Mesoudi et al., 2006).

Coren (2003) as many others already pointed out the growth of information and the escalation of logistic behavior as a characteristic element of evolution. Other ideas for general principles to understand evolution and a periodization of the timeline are:

- self-organization (Jantsch, 1980),
- non-equilibrium steady-state transitions (NESST) (Aunger, 2007a),
- energy-flow (Chaisson, 2002; D. J. LePoire, 2015; D. J. LePoire & Chandrankunnel, 2020; Schneider & Kay, 1994),

However, some proposals for the periodization of evolution (Kurzweil, 2005; Modis, 2002; Panov, 2005) are not based on objective principles, but merely on a subjective perception of evolutionary milestones.

In contrast to other disciplines such as geology, there are still no generally accepted principles for the periodization of big history. However, there is an ongoing debate about how best to periodize the evolutionary timeline (D. LePoire, 2023; Solis & LePoire, 2023). Periodization raises three questions, among others: What general principle should periodization be based on, why is evolution evolving faster and faster, and will there be a singular point (A. V. Korotayev & LePoire, 2020) in the near future where the further development of evolution changes qualitatively?

Comparing the methodology of the general theory of evolution with the methodology of other authors (see Chap. 8.1), we argue that the general theory of evolution may indeed be a favorite for a unified view of biological and cultural evolution and its periodization because it develops the idea of information as an essential element for understanding evolution and its periodization in a stringent and comprehensive way.

The basic idea (see Chap. 2) is to consider not only the evolution of genetic information - as Darwin did - but the evolution of very general information, which of course includes the evolution of genetic and cultural information. It can be seen that evolution is characterized by the fact that new types of information have developed in leaps and bounds. Each type has subsequently developed in 3 successive stages: new storage technology, new duplication technology and new processing technology. This uniform concept of evolution makes it possible, among other things, to:

- achieve a unified view of biological and cultural evolution
- find a common natural periodization of the evolution (see Chap. 3 and Chap. 8.1) for
    - Living being forms (see Chap. 4)
    - Evolutionary systems and cooperation mechanisms (see Chap. 4)
    - Variation mechanisms (see Chap. 4)
    - Debt creation (see Chap. 5)
    - Driving forces (see Chap. 6)
- understand the exponential acceleration of evolution through the emergence of targeted variation mechanisms (see Chap. 7).

2. Basic ideas and terms of the general evolutionary theory

2.1. Terms of the general evolutionary theory

The basic concern of the general evolutionary theory is to understand the biological, technological, social and economic structures of evolution from the origin of life to the present and into the future from a unified perspective and structure.

The general evolutionary theory can be seen as a comprehensive generalization and extension of Darwin's theory of evolution. The general theory is neither about modifications of Darwin's theory in the sense of the synthetic theory of evolution (see e.g.(Lange, 2020)) nor about the expansion of the concept of selection to include multilevel selection (D. S. Wilson & Sober, 1994) nor about new findings from evolutionary developmental biology (Evo-Devo) (Müller & Newman, 2003) nor epigenetics research. The general evolutionary theory goes far beyond this. It extends the terms "biological species", "genotype", "phenotype", "mutation" and "selection" corresponding to the Darwinian theory and replaces them with much more general terms: (see *Table 1*).

Darwinian evolutionary theory	→	General evolutionary theory
Biological species	→	Species (in a broader sense)
Genetic information, genotype	→	General information
Phenotype	→	Form
Mutation mechanism, mutation	→	Variation mechanism, variation
Selection system	→	Evolutionary system

Table 1: Terms of the general evolutionary theory

These conceptual extensions allow evolutionary developments in quite different fields to be described from a unified point of view and within a unified time frame. See examples in *Table 2*.

Just as a biological species is characterized by its genetic information (genotype) and the biological traits of the corresponding organism (phenotype), a "species in a broader sense" is characterized by a certain general information and the traits of the resulting form.

Just as a selection system describes the survival of the best adapted phenotype resp. biological species and their genetic information, evolutionary systems describe the dynamics of the frequencies of the best adapted forms, resp. species in a broader sense and the underlying general information. Typically, dynamics of evolutionary systems and as special case selection systems are formally described by differential equation systems.

$$\frac{dn_i}{dt} = f(n, p) \qquad n = (n_1, n_2, ...) \qquad \textit{frequencies of species}$$

$$p = (p_1, p_2, ...) \qquad \textit{parameters}$$

Biology	Hominins → homo → homo sapiens
Data types	RNA → DNA → electrochemical potential
Targeted variation mechanisms	Imitation → learning → teaching
Technologies	Writing → letterpress → computing
Monetary systems	Commodity money → coin money → paper money → electronic money
Economic systems	Barter → division of labor → investment
Economic regimes	Market economy → capitalist market economy → global capitalist market economy
Cooperation	Group coop. → direct coop. → debt coop. → indirect coop. → norms coop.
Driving forces	Gradient of concentration → gradient of electrochemical potential → gradient of utility

Table 2: Examples of evolutionary developments in quite different fields

Just as mutation mechanisms lead to mutations (i.e. changes in the genetic information of the genotype and traits of the phenotype), variation mechanisms lead to variations of the parameters p to p' (i.e. lead to changes in the general information and traits of the form). These terms are explained in more detail using 3 examples:

Example 1 from Darwin's theory of evolution:
DNA is a technology for storing genetic information. The DNA leads to a biological trait of a phenotype A. This genetic information can be changed into new genetic information by a mutation mechanism (chance, chemical substances, radiation, etc.). This new genetic information is called a mutation. It leads to an organism B with a changed biological trait. The development over time of the frequencies of A and B are described by a differential equation system which is called selection system. If the reproduction rate of B is greater than the reproduction rate of A, the offspring of B will reproduce faster than the offspring of A and the relative frequency of B increases over time and that of A decreases ("survival of the fittest").

Example 2 from the general evolutionary theory:
Each biological species of mammals is characterized by its specific genetic information (genotype), from which the specific organism with its traits (phenotype) arises. Analogously, a market economy occurs in different species (in a broader sense). Each particular type of market economy is shaped by a variety of different general information, such as technological knowledge, governmental norms of behavior, education of people, etc. This specific general information gives rise to a particular form of economic activity with all its traits, e.g. the capitalist market economy or one of its special forms.

Example 3 from the general evolutionary theory:
The neural network in the human cerebrum is a technology for storing general information, such as complex causal relationships, e.g: "If you look for wild grain, you will find food". This general information leads to a certain behaviour. It can be changed into a new causal relationship through the variation mechanism "learning", e.g: "If you don't eat all the cereal grains, but sow some of the cereal grains, you will no longer need to search for cereal grains, but can harvest more cereal grains". This new causal relationship stored in the cerebrum (grow grain → eat more) is therefore a variation of the old causal relationship (look for grain → eat). The old causal relationship leads to an evolutionary system that describes the temporal development of the gatherer's frequencies. The new one leads to a new evolutionary system that describes the temporal development of the frequencies of the sower and its food.

There are some specific important evolutionary systems:

- Selection systems: The frequency of one individual increases, while that of others decreases.
- Win-win systems: The frequency of two, resp. all, individuals involved increase.
- Prisoner's dilemma systems: These evolutionary systems are called prisoner's dilemmas, because they lead to a case that appears paradoxical at first glance. Although the fitness (reproductive rate) of the pure

species of cooperators is greater than the fitness (reproductive rate) of the pure species of defectors an arbitrarily small set of defectors will finally displace all cooperators.

- Cooperation systems: The overcoming of prisoner's dilemmas is a very important achievement of evolution. Variation mechanisms that enable prisoner's dilemmas to be overcome are called cooperation mechanisms and the resulting systems are called cooperation systems.

2.2. From Darwin's theory of evolution to the general evolutionary theory in 3 steps

The basic idea is, not only to consider - as Darwin did - the evolution of genetic information, but instead to consider the evolution of very general information. It shows that evolution is characterized by the fact, that new types of information have developed in leaps and bounds, with new storage technologies, new duplication technologies and new processing technologies. Furthermore, it shows that each new information technology has led to increasingly well-targeted variation mechanisms, that have exponentially accelerated evolution.

Darwinian theory:

Let's start with the basic concept of Darwinian theory: A selection system (usually a differential equation system) describes the dynamics of the frequencies of genotypes. A mutation mechanism leads to a new genotype and thus to a new phenotype with a new trait. This leads to a new selection system with changed parameters and the Darwinian cycle starts all over again (see *Figure 1*).

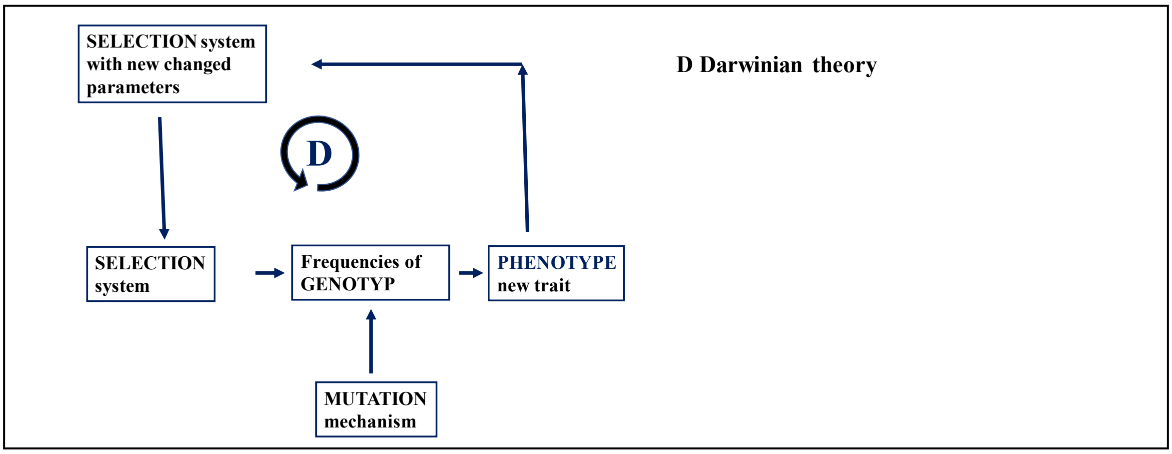

Figure 1: Darwinian theory

First Step:

In a 1st step of extension, we extend Darwinian terms:

- Instead of genetic information, we consider general information, e.g., content of consciousness, cultural behavior or constitutional laws.
- Instead of phenotypes, we consider forms, e.g. agriculture or livestock breeding.
- Instead of mutation mechanisms for genetic information, we consider variation mechanisms for general information, e.g. imitation, learning, teaching, logical reasoning.
- Instead of simple selection systems, we consider general evolutionary systems, e.g. the prisoner's dilemma or, e.g., the evolutionary systems resulting from the different cooperation mechanisms.

This results in the Darwinian cycle for the extended terms (*Figure 2*)

- selection system is replaced by evolution system,
- genetic information by general information
- mutation mechanism by variation mechanism
- and the term phenotype is replaced by the term form

Second Step:

If the Darwinian cycle has been run through many times, a qualitative leap in biological traits can occur. The general theory in a 2nd step (*Figure 3*) assumes that the evolutionary leaps fundamental to evolution, lead to the appearance of new information technologies. First, for each new type of information a storage technology emerges, resulting in a qualitatively new evolutionary system. Subsequently, the Darwinian cycle is run again, until there is another leap, which results in a new duplication technology and a qualitatively new evolutionary system. After further runs, a new processing technology and finally a new type of information occurs and the process of the emergence of new technologies and qualitatively new evolutionary systems starts all over again.

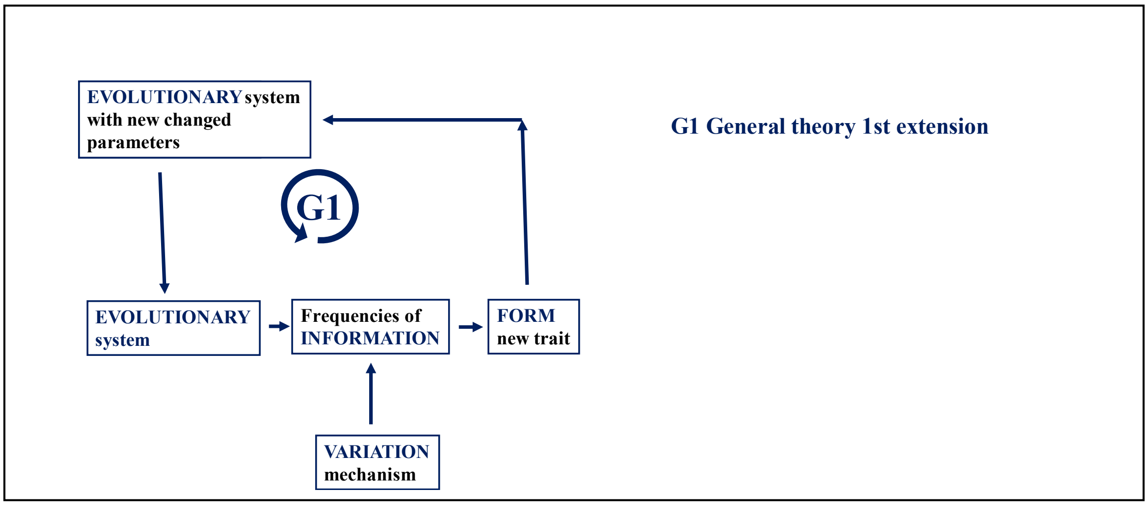

Figure 2: General theory 1st extension

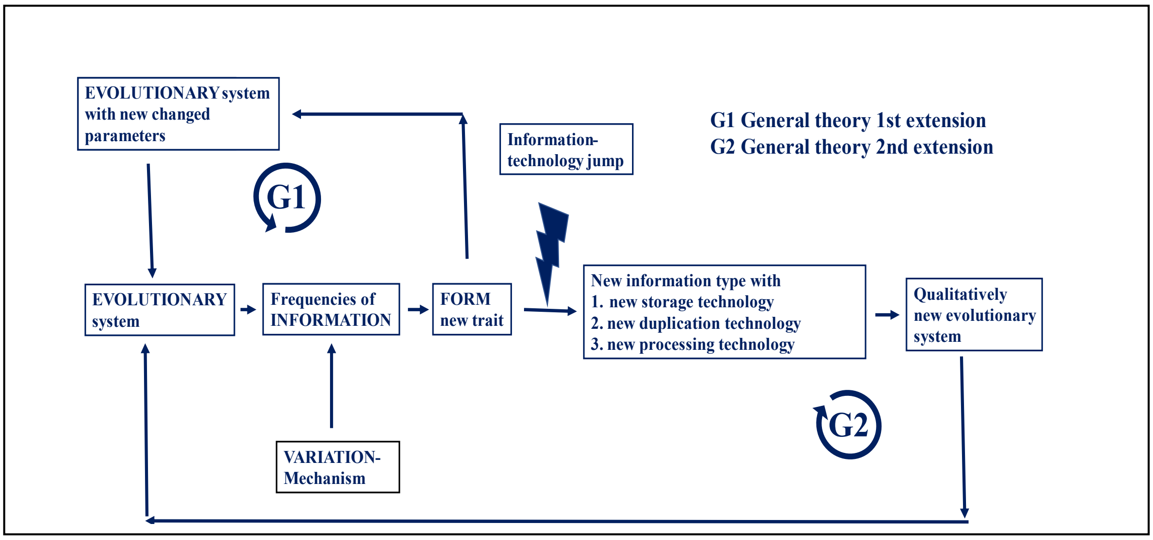

Figure 3: General theory 2nd extension

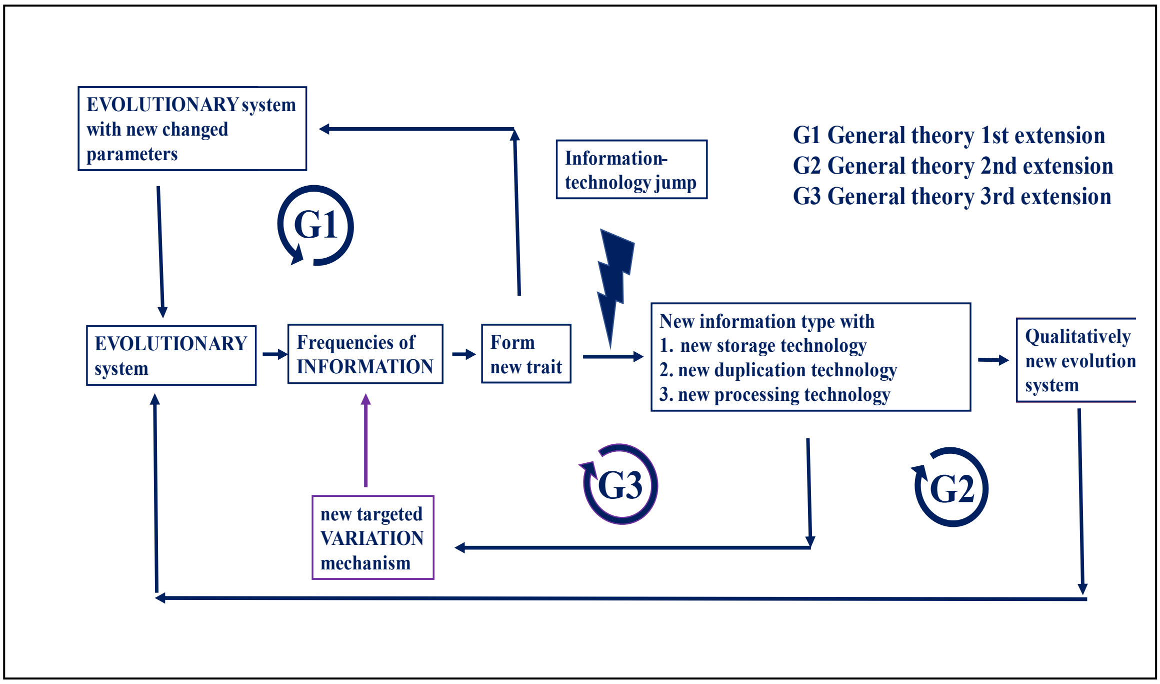

Figure 4: General theory 3rd extension

Third Step:

In a 3rd essential step of extension (*Figure 4*), one can show that each new information technology leads to a new variation mechanism, in particular to targeted variation mechanisms. The higher the information technology is developed, the more the new variation mechanisms are targeted.

Examples of targeted variation mechanisms are: horizontal gene transfer, imitation, learning, teaching, logical reasoning, utility optimization, investment, or genetic manipulation. Targeted variation mechanisms do not change information in a completely random way, but change information with information that has already *proven to be advantageous* in a previous evolutionary system. Targeted variation mechanisms have a particularly high influence on the speed of evolution, because, to a certain extent, they shorten evolutionary detours and avoid erroneous developments. They are therefore a very significant cause of the fact, that evolution is proceeding faster and faster. For further details, see Chap. 0.

3. Natural periodization of evolution (evolutionary theory of information)

One of the important results of the general theory is that it leads to a common natural periodization of evolution based on the emerging new information technologies. Therefore, we call this periodization also the evolutionary theory of information. If we compare the methodology of the general theory with other methodologies (see Chapter 8.1), we consider it justified to call the classification and periodization within the framework of the general evolutionary theory the "natural" periodization of evolution on Earth, since it is based on a simple logical and easily understandable common principle for all evolution.

Overall, the entire development on earth from the beginnings to the present can be divided into 8 ages, which correspond to the times when the 8 types of information first appeared. It should be noted that in the following, when we speak of a point in time when a technology "first appeared", we actually mean more precisely, firstly, that this technology has established itself in an efficient form and secondly, that it has led to far-reaching changes.

These ages correspond to the following 8 information types resp. storage technologies: Crystal, RNA, DNA, nervous system. cerebrum, external local data, the cloud as external dislocated networked data and a future information type which is based on quantum computers. Each of these ages can generally be divided into three successive subages, in each of which a new storage, duplication or processing technology develops (*Table 3*).

Age [0], the age of inanimate matter, 4.6 billion until 4.4 billion years ago:

- In the age [0], digital information was generated and stored by the trait of **self-organization of inorganic matter** through crystallization as a result of falling temperatures 4.6 billion years ago.
- No duplication or processing technologies were possible by crystals.

Age [1], the age of RNA, 4.4 billion until 3.7 billion years ago

- In the subage [1.1] probably about 4.4 billion years ago further decreasing temperatures and the existence of crystals enabled the biological trait of **self-organisation of organic matter** at crystal surfaces in the form of RNA strings. This led to the creation and storage of much more information as in age [0].
- In the subage [1.2] about 4.0 billion years ago (Stone, 2013) the biological trait of **autocatalysis** enabled the duplication of RNA (Altman, 1989).
- No processing technologies were possible in age [2].

Age [2], the age of DNA, 3.7 billion until 630 million years ago:

- In the subage [2.1] about 3.7 million years ago (Dodd et al., 2017) the biological traits of **DNA** and the **genetic code** evolved. Together with the genetic code, DNA is a storage technology for the information on how the phenotype is built up.
- In the subage [2.2] about 2.1 billion years ago (Sánchez-Baracaldo et al., 2017; Veyrieras, 2019) the biological trait of **cell division** and **cell association** evolved. It is a duplication technology for phenotypes.
- In the subage [2.3] probably about 1 billion years ago the biological trait of **sexual reproduction** evolved. Evidence for the existence of sexual reproduction has been found for the time before 565 million years ago (Droser, 2008), but it is likely that it evolved much earlier, probably about 1 billion

years ago. It is a processing technology which forms a new genetic information out of the genetic information of the male and female.

Age	Start years ago	Information type (Storage medium) Information technology
[0]	4.6 x 10^9	Crystal
[0]	4,6 10^9	Self-organization of inorganic matter
[1]	4.4 x 10^9	RNA
[1.1]	4,4 10^9	Self-organization of organic matter
[1.2]	4,0 10^9	Autocatalysis
[2]	3.7 x 10^9	DNA
[2.1]	3,7 . 10^9	Genetic code, phenotype formation (Dodd et al., 2017)
[2.2]	2,1 . 10^9	Cell division, cell association
[2.3]	1,0 . 10^9	Sexual reproduction (Droser, 2008)
[3]	630 000 000	Nervous system
[3.1]	630 000 000	Nerve cells/monosynaptic reflex arc
[3.2]	550 000 000	Brainstem/polysynaptic reflex arc
[3.3]	66 000 000	Limbic system
[4]	6 000 000	Cerebrum
[4.1]	6 000 000	Neural network / storage of causal relations
[4.2]	900 000	Simple language / duplication of experience
[4.3]	60 000	Cognitive revolution / logical reasoning
[5]	5 000	External local digital data
[5.1]	5 000	Writing/ external storage of digital data
[5.2]	500	Letterpress/ External duplication of digital data
[5.3]	50	EDP/ external processing of digital data
[6]	10	Cloud (external dislocated networked data)
[6.1]	10	Internet/networked storage/duplication networked data
[6.2]	Present	Storage/ duplication/ processing of big data, AI 1.0
[7]	Future	Analog data in quantum computer / AI 2.0

Table 3: Ages and subages of the natural periodization

Age [3], the age of the nervous system, 630 million until 6 million years ago:

- In the subage [3.1] about 630 million years ago (Podbregar, 2019; Rigos, 2008) the biological trait of **nerve cells** with the so-called **monosynaptic reflex arc** developed. This enabled the first sensors. These biological traits enable information about the environment to be perceived and stored as electrochemical information. The organism can react to this information with a simple immediate response known as the monosynaptic reflex arc.
- In the subage [3.2] that began with the Cambrian revolution about 550 million years ago, the biological trait of the **brain stem** developed which enables the so-called **polysynaptic reflex arc**. The brainstem stores and duplicates the information about the environment to enable the polysynaptic reflex arc to trigger an immediate response in several different organs of the organism.
- In the subage [3.3], about 66 million years ago, the biological properties of the **limbic system** reached their full expression. It enables a processing technology for external and internal information. The

essential property of the limbic system is to reduce and classify information to classes which lead to the same reaction of the body: emotions, feelings, behavior.

Age [4], the age of the cerebrum, 6 million years until 5,000 years ago:
- In the subage [4.1] about 6 million years ago the biological trait of the **high-quality associative neural network** in the cerebrum evolved. It makes a storage technology possible, which can store "complex consciousness contents", especially individual experience and simple causal relationships**.**
- In the subage [4.2] about 900,000 years ago the biological trait of a **simple language** evolved. It is an efficient duplication technology for individual experience.
- In the subage[4.3] about 60,000 years ago, a superabundance of new biological traits evolved, collectively referred to as the **cognitive revolution**. All these new traits developed in close connection with the trait of an **abstract language** with a sentence structure consisting of abstract words and grammar. A very important trait that has developed simultaneously and within the framework of abstract language is **logical reasoning** as a processing technology for the contents of consciousness.

Age [5], the age of external local digital data, 5.000 until 10 years ago:
- In the subage [5.1] about 5.000 years ago the biological-technological trait of **writing** evolved. It is a storage technology, which can store digital data in an external device**.**
- In the subage [5.2] about 500 years ago the technological trait of **letterpress** was evented. It is an efficient duplication technology for external digital data.
- In the subage [5.3] about 50 years ago the technological trait of **EDP** (electronic data processing) was evented. It is an efficient processing technology for external digital data.

Age [6], the age of the cloud (external delocalized networked digital data), 50 years ago until the present:
- In the subage [6.1] about 10 years ago the technological trait of an efficient widely used **Internet** emerged. It is a storage that makes duplication technology redundant, as in principle everyone has access to the information stored on the Internet.
- In the subage [6.2], the present, the technological trait of **artificial intelligence 1.0** is emerging just now. Artificial intelligence 1.0 produces new information by a statistical processing of big data stored in the Internet. Virtual reality is created by processing information about reality with information from the Internet.

Age [7], the age of analog data in quantum computers:
- The age [7] lies in the future and is probably characterized by the technological trait of quantum computers. This trait will enable storage, duplication and processing in a single technology. Artificial intelligence 2.0 produces new information not by a statistical processing but by logical processing of big data in the Internet. AI 2.0 will be incredibly more efficient in producing evolutionarily successful information than anything we can currently imagine.

4. Natural periodization of living being forms, evolutionary systems, cooperation mechanisms and targeted variation mechanisms

It turns out that there is a very close relationship between the periodization of evolution based on new information technologies (evolutionary information theory), which we presented in Chap. 3, and the evolution of biological, technological and social structures. Evolutionary information theory is thus the theoretical key to understanding evolution in a very general sense.

The respective information technologies can be understood as characteristic biological-technological traits of the species of the respective age. They typically also represent the preconditions for the development of the evolutionary systems and variation mechanisms characteristic of the species of the respective age. The periodization of species in a broader sense (living beings and forms), evolutionary systems and variation mechanisms thus results directly from the periodization of information technologies, as described in Chap. 3. The resulting periodization is described in detail in *Table 4* and below.

For a comparative overview of the different cooperation systems see Chap. 5 and for a comparative overview of the different targeted variation mechanisms see Chap. 7.

Age	Living being, Form	Evolutionary system, Cooperation system	Variation mechanism
[0]	Inanimate matter	Crystallization	Temperature, pressure
[1.1]	RNA molecules	Creation-destruction	Environmental change
[1.2]	Ribocytes (Altman, 1989) (Eigen & Schuster, 1979)	Genotype selection (survival of the fittest genotype)	Mutation, constraints
[2.1]	Single-celled	Phenotype selection (survival of the fittest phenotype)	Epigenetic variations
[2.2]	„Simple“ multicellular	Network-win-win systems	Horizontal gene transfer
[2.3]	„Higher“ multicellular	Sexual win-win	Sexual reproduction
[3.1]	Monosynaptic animals („first eating“ animals)	Predator-prey, prisoner's dilemma, network cooperation	Network formation, swarm formation
[3.2]	Polysynaptic animals (apterygota, insects, fish, amphibians, reptiles, early birds, early mammals)	Group cooperation	Group formation, learning of statistical relationships
[3.3]	Limbic animals (higher birds, higher mammals)	Direct cooperation	Emotion formation, imitation, learning of near-time causal relationships
[4.1]	Hominins	2-sided debt cooperation	Testing of time-delayed causal relationships
[4.2]	Homo	Indirect coop. (social debt), Barter	Teaching
[4.3]	Homo sapiens (Wiese, 2004b, 2004a)	Norms cooperation, Division of labor, Commodity money	Logical reasoning, individual utility optimization
[5.1]	Market economy (Brodbeck, 2009)	Religious norm systems, individual contracts, Regional trade (coin money)	Quantitative individual economic utility optimization, animal and plant breeding
[5.2]	Capitalist market economy	National systems of norms, National trade (paper money)	Investment in real capital
[5.3]	Global capitalist market economy	International norms, World Trade (fiat money)	Investment in human capital
[6.1]	Internet society	Global sanctions, Internet trade (electronic money)	Investment in data capital
[6.2]	AI society	Stabilization based on automatic global sanctions, Blockchain money	Investment in stability and resilience, gene manipulation
[7]	Cyborg	Human-machine symbiosis, Completely new form of social organization	Overall utility maximization

Table 4: The periodization of species in a broader sense (living beings and forms), variation mechanisms and evolutionary systems

4.1. Age [0], the age of inanimate matter

The trait of **self-organization** of inorganic matter is a technology for creation and storage of information which is stored in form of crystals.

Evolutionary systems:

The crystallization process in its simplest form is described by the evolutionary system

$$\frac{dn_A}{dt} = a_A \qquad a_A > 0$$

Variation mechanisms:

environmental conditions
Changes in environmental conditions, e.g. an increase in temperature or a change in pH, can lead to a different rate of creation or a different rate of destruction. Therefore, the change of environmental conditions can be formally considered as a variation mechanism, because they change a_A and b_A.

4.2. Age [1.2], the age of ribocytes

The biological trait of **autocatalytic growth** is an information duplication technology which enabled the duplication of RNA (Altman, 1989). This is described by the theory of hypercycles (Eigen & Schuster, 1979).

Evolutionary systems:

Autocatalysis
Autocatalysis in its simplest form is described by the evolutionary system

$$\frac{dn_A}{dt} = b_A n_A$$

The RNA complexes formed in this way are called ribocytes. They can be regarded as the first species of living organisms.

Genotype selection system
If the growth rate (fitness) of A is greater than the growth rate (fitness) of B, i.e., $b_A > b_B$, the evolutionary system

$$\frac{dn_A}{dt} = b_A n_A$$
$$\frac{dn_B}{dt} = b_B n_B$$

leads to the relative frequency of B approaching 0 and the relative frequency of A approaching 1 over time. This is exactly the formal description of what is meant by selection. Ribocytes consist only of RNA, i.e. the carriers of genetic information. Selection therefore results directly from the traits (e.g. growth rate) of the RNA and therefore takes place directly at the level of genetic information. It can therefore also be called genotype selection ("survival of the fittest genotype").

Variation mechanisms:

Mutation
The mechanism of duplication of information by autocatalysis was the precondition for the occurrence of mutation as variation mechanism. Random duplication errors, high-energy radiation or chemical substances can change individual nucleotides and lead to RNA A becoming RNA B with an altered growth rate.
Thus, the mutation mechanism changes the parameters of the evolutionary system and is therefore a special variation mechanism.

Constraints
Limited resources represent a constraint on the sum of individuals that can survive. They lead to the reduction of birth rates and the formation or increase of death rates and thus represent a variation mechanism. For details see (Glötzl 2023b, Chap.11.3).

4.3. Age [2.1], the age of single-celled organisms

The biological traits of **DNA and the genetic code** make it possible to store a new type of information, the information for the building plan of the phenotype in the form of the sequence of nucleotides and amino acids respectively.

Evolutionary systems

Phenotype selection
The evolutionary system "survival of the fittest" no longer takes place directly at the level of genes, but at the level of phenotypes and organisms respectively. The creation of organisms was therefore the precondition for the creation of the evolutionary system phenotype selection ("survival of the fittest phenotype"). Formally, it is described by the same differential equation system as genotype selection. The only difference is that n_A, n_B describe frequencies of phenotypes instead of genotypes.

Variation mechanisms

Epigenetics
Examples of epigenetic modification mechanisms are DNA methylation and histone modification, which change the way genes are expressed without changing the underlying DNA sequence. The prerequisite for the possibility of epigenetic modification mechanisms is obviously the formation of phenotypes. Epigenetic mechanisms have therefore been able to form at the earliest in the age [2.1]. Because epigenetic changes play an essential role in cell differentiation, they have subsequently acquired a particularly important function in the age [2.2], the age of higher multicellular organisms.

4.4. Age [2.2], the age of “simple” multicellular organisms

The biological trait of **cell division** is a duplication technology for information. Together with the trait of **cell association** it leads to 2 consequences:
If the cells are of the same type, this leads to simple multicellular organisms. The remaining of new cells created by cell division in the common cell complex corresponds to an intraindividual duplication of genetic information. If the cells are different, the cohesion of the cells allows horizontal gene transfer.

Evolutionary systems

Network win-win system
The meeting resp. interaction of 2 cells can lead to a win-win situation for both cells A, B. It is described by the evolutionary system

$$\frac{dn_A}{dt} = b_A n_A + c_{AB} n_A n_B \qquad c_{AB} > 0$$
$$\frac{dn_B}{dt} = b_B n_B + c_{BA} n_A n_B \qquad c_{BA} > 0$$

Variation mechanisms

Horizontal gene transfer
If different cells remain spatially attached to each other some time, the exchange of genetic information between these cells can occur. This leads to a change in genetic information, which is called horizontal gene transfer. The difference to a mutation is fundamental:
a) not only one base is changed, but many bases are changed at the same time.
b) Horizontal gene transfer is what we call a *targeted variation mechanism*. Information is not changed in a completely random way as is the case for mutations, but information is changed with information that has already proven to be advantageous in a previous evolutionary system, namely the other cell. Targeted variation mechanisms have a particularly high influence on the speed of evolution, because, to a certain extent, they shorten evolutionary detours and avoid erroneous developments that would occur if only mutations were

possible. They are therefore a very significant cause of the fact, that evolution is proceeding faster and faster (see Chap. 7). Horizontal gene transfer plays a particularly important role in prokaryotes and is a precursor of the mechanism of sexual reproduction in age [3.1].

4.5. Age [2.3], the age of "higher" multicellular organisms

Multicellular organisms with differentiated cells and sexual reproduction we call "higher" multicellular organisms. The biological trait of **sexual reproduction** is an information processing technology.

Evolutionary systems

Sexual win-win systems
Sexual reproduction leads to very complex evolutionary systems. The complexity stems, among other things, from the specific advantages and disadvantages of sexual reproduction.
Advantage: enormously increased adaptability.
Disadvantage: the sexual partners must find each other. This can be achieved either by a very high number of offspring, so that the probability of the sexual partners meeting was high enough, or the development of sensors that made it easier to find the sexual partners. The first such sensors were based on the possibility of detecting concentration gradients of special chemical molecules (e.g. pheromones).

Kin evolutionary systems (often called kin selection systems or inclusive fitness)
There was a hard discussion whether kinship can lead to cooperation. We share Nowak's and Wilson's view that this is not the case (Nowak et al., 2010)

Variation mechanisms

Sexual reproduction for itself is a targeted variation mechanism similar to horizontal gene transfer.

4.6. Age [3.1], the age of monosynaptic animals

The biological trait of **nerve cells with a monosynaptic reflex arc** as storage technology enabled the storage of a new information type: information about the environment in form of electrochemical information. It has led to the formation of the first efficient direction-sensitive sensors (e.g. hearing and seeing) that could detect environmental information from a greater distance. This was the precondition for animals to eat plants and other animals. The existence of plant eating and predatory animals has dramatically increased the pressure to adapt in general. This has resulted in species complexity evolving at an exponentially increasing rate following this age.

For details of the following evolutionary systems and variation mechanisms see (Glötzl, 2023b).

Evolutionary systems

Interaction systems
Nerve cells with a monosynaptic reflex arc were the preconditions for the existence of evolutionary systems with interactions between individuals. Important examples of interaction between individuals are: Eating, altruism, selfishness. All these evolutionary systems for 2 interacting individuals A and B are in its simplest form of the type

$$\frac{dn_A}{dt} = a_A + b_A n_A + c_{AA} n_A n_A + c_{AB} n_A n_B + c_{BA} n_B n_A + c_{BB} n_B n_B$$
$$\frac{dn_B}{dt} = a_B + b_B n_B + c_{BB} n_B n_B + c_{BA} n_B n_A + c_{AB} n_A n_B + c_{AA} n_A n_A$$

where the latter terms describe the interactions between A and B. Special cases are such important evolutionary systems as the predator-prey system or the prisoner's dilemma system or cooperation systems.

Predator-prey system

$$\frac{dn_A}{dt} = (-b_A + c_{AB}n_B)n_A = -b_A n_A + c_{AB}n_A n_B \qquad A\ predator$$

$$\frac{dn_B}{dt} = (+b_B - c_{BA}n_A)n_B = +b_B n_B - c_{BA}n_B n_A \qquad B\ prey$$

$$with$$

$$b_A > 0 \quad death\ rate\ of\ A$$

$$c_{AB}n_B > 0 \qquad birth\ rate\ of\ A$$

$$b_B > 0 \qquad birth\ rate\ of\ B$$

$$c_{BA}n_A > 0 \qquad death\ rate\ of\ B$$

Prisoner's dilemma system

$$\frac{dn_K}{dt} = c_{KK}n_K n_K + c_{KD}n_K n_D \qquad K\ cooperator$$

$$\frac{dn_D}{dt} = c_{DK}n_D n_K + c_{DD}n_D n_D \qquad D\ defector$$

$$with\ the\ prisoner's\ dilemma\ condition$$

$$c_{DK} > c_{KK} > c_{DD} > c_{KD} \quad and \quad 2c_{KK} > c_{DK} + c_{KD}$$

This evolutionary system is called prisoner's dilemma, because if prisoner's dilemma condition is fulfilled it leads to a case which at first sight seems paradoxical. Although the fitness (reproductive rate) of the pure species K (cooperators) is greater than the fitness (reproductive rate) of the pure species D (defectors) an arbitrarily small set of defectors finally displaces all cooperators.

Network cooperation system (often called network selection)

$$\frac{dn_K}{dt} = c_{KK}n_K n_K + c_{KD}n_K n_D$$

$$\frac{dn_D}{dt} = c_{DK}n_D n_K + c_{DD}n_D n_D$$

$$with\ c_{DK} < c_{KK}$$

Overcoming prisoner's dilemmas is a very important achievement of evolution. Variational mechanisms that enable prisoner's dilemmas to be overcome are called cooperation mechanisms and the resulting systems are called cooperation systems. The first cooperation system to appear in evolution is the system of network cooperation (often referred to as network selection.

Variation mechanisms

Network formation
A simple case of cooperation mechanism is network formation in the form that in the network cooperators are more often surrounded by cooperators and defectors are more often surrounded by defectors, whereas cooperators and defectors are rarely neighbors of each other. If the network formation in this sense is high enough, the Prisoner's dilemma is overcome, i.e., the cooperators can no longer be displaced by defectors. Thus network formation is a targeted variation mechanism because it influences fitness not in a random way but in a way to increase the fitness of all individuals.

Swarm formation
Swarm formation is a targeted variation mechanism, which immediately changes the animal's behavior not random but towards a statistical average movement of animals in the neighborhood, which with high probability has proven to be advantageous.

4.7. Age [3.2], the age of “higher” animals (apterygota, insects, fish, amphibians, reptiles, early birds, early mammals)

During the Cambrian the first explosion of biodiversity occurred. A more complex nervous system led to the biological trait of the **polysynaptic arc** as an information duplication system**,** meaning that an incoming piece of information was multiplied and triggered multiple reflexes. This more complex nervous system subsequently evolved into what is now called the **brainstem** (Truncus cerebri or colloquially, the reptilian brain). The brainstem controls vital functions such as reflexes, breathing, heartbeat, eating, fighting, fleeing, etc.

Evolutionary systems

Group cooperation
The precondition of group cooperation was the possibility of group formation.

Variation mechanisms

group formation
Preconditions for group formation are:
- the individuals must be complex enough to be able to form appropriate group recognition traits (e.g. smell, song, visual traits),
- the individuals must have sensors to be able to perceive these recognition characteristics,
- individuals must have at least a polysynaptic reflex arc to be able to respond differently to group members and non-group members in terms of frequency and quality of interaction.

These biological-cognitive preconditions were first present in the subage [3.2].

Learning statistical relationships
Learning statistical relationships means learning and memorizing "if event A occurs often, event B usually occurs as well". Thereby the information stored in the brainstem is changed not in a random way, but in a way which increases the fitness of the individual. Therefore, learning statistical relationships can be seen as a targeted variation mechanism.

4.8. Age [3.3], the age of higher birds and higher mammals

The biological trait of the **limbic system** (or colloquially, the mammalian brain) represents an information processing technology for external and internal information. The essential property of the limbic system is to reduce and classify information to classes which lead to the same reaction of the body: emotions, feelings, behavior.

Evolutionary system

direct cooperation
The precondition of direct cooperation is direct reciprocity.

Variation mechanisms

Direct reciprocity
The limbic system was a precondition for direct reciprocity, what is also called “tit for tat” or “you me so me you”.

Imitation
Furthermore, the limbic system enabled the targeted variation mechanism of imitation.

Learning of near-time causal relationships
An important characteristic of the cerebrum of higher birds and higher mammals is the ability to recognize a causal relationship between events X and Y, which are in a direct temporal connection, from their own experiences and to store them as information in the form "if X, then also Y". Obviously, learning does not change information randomly and is a *targeted variation mechanism*.

4.9. Age [4.1], the age of hominins

The biological trait of the **high-quality associative neural network** in the cerebrum enables the storage of a new type of information, namely the storage of complex consciousness content.

Evolutionary systems

2-sided debt cooperation (bilateral debt cooperation)
The ability to document debt relationships is fundamental to the development of win-win systems and cooperation systems based on debt. *Win-win systems* and all *cooperation systems* have a tremendous influence on evolution, because they lead to a major survival advantage for all individuals involved. Debt relations are complex consciousness content and need an appropriate storage technology. Therefore, the more efficient a mechanism for documenting debt is, the easier it is for win-win situations to develop. The first technology for storing debt relations was the high-quality associative neural network in the cerebrum. For a detailed discussion of the importance of debt, see (Glötzl, 2023b). Some important aspects are outlined in Chap. 5.

Variation mechanisms

Testing of time-delayed causal relationships
Unlike higher birds and higher mammals, hominins are able to recognize causal relationships between events that are separated in time or space. Furthermore, they are able to test these relationships in simple experiments.

4.10. Age [4.2], the age of homo

The biological trait of a **simple language** as information duplication technology characterizes the age of homo. It should be noted that the language of animals in the form of acoustic, visual and chemical signals, in contrast to the simple language of homo, is essentially limited to the communication of e.g. warning, fear, sexual lure signals and indications of food availability.

Evolutionary systems

Indirect cooperation (indirect reciprocity)
Without a simple language as it was in age [4.1], presumably only 2-sided (bilateral) social debt relationships were possible. Only the development of a simple language as an efficient duplication technology of information has made the creation of more complex debt relations possible. These include, above all, social debt relationships to an entire social community. Social debt relations towards the whole social community play an important role especially in the cooperation mechanism of indirect reciprocity. If an individual provides a service without direct compensation, this can lead to an increase in the reputation of this individual in the community. Reputation can be interpreted as the documentation of a debt obligation of the community towards the individual or as a debt claim of the individual towards the community.

Barter
The barter of goods is a win-win mechanism that also requires at least a simple language.

Variation mechanisms

Teaching
The targeted variation mechanism of teaching is nothing else than to communicate experiences or to pass on complex skills in an efficient way. This was only possible through the development of a simple language. Before the development of the variation mechanism teaching, the use of tools only played a subordinate role. Recognizing causal relationships and communicating them through teaching is the precondition for the efficient construction and comprehensive use of tools. This means that consciously built tools are formed through targeted variation of information stored in the cerebrum.

4.11. Age [4.3], the age of homo sapiens

All the biological traits of **cognitive revolution** as e.g. **logical reasoning** evolved in strong connection to the trait of an **abstract language** with sentence structure from abstract words and grammar. Abstraction and logical thinking are the most important forms of processing of consciousness contents. Abstract language was thus the basis for the cognitive revolution. For details see (Glötzl 2023b, Chap. 5.13). Here we give only a brief summery.

Evolutionary systems

Norms cooperation
In principle, in a prisoner's dilemma situation, a punishment for incorrect behavior and/or a reward for cooperative behavior can lead to the prisoner's dilemma being overcome and cooperation prevailing. This may have already played a role sporadically before the time of homo sapiens. However, this only became of formative importance when homo sapiens had the preconditions for the creation of immaterial realities due to the cognitive revolution. Only then was it possible to establish simple social norms by means of simple religions. In social terms, religions - in addition to the enforcement of individual claims to power - have ultimately always had the enforcement of cooperation through punishment and reward as their target.

Division of labor:
Efficient division of labor presupposes that services and reciprocations can be provided at different times. The division of labor is therefore significantly promoted by the ability to document debts efficiently. This was made possible for the first time by debts on commodities and the ability to count. The emergence of a clear concept of numbers is in turn very closely linked to the existence of an abstract language (Wiese, 2004b, 2004a). All of this explains why an efficient division of labor only developed with homo sapiens.

Variation mechanisms

Logical reasoning:
Logical thinking does not lead to random changes of information, but is a particularly efficient targeted variation mechanism. In this mechanism, already existing successful information is not adopted by imitating, learning or teaching, but new information successful for evolution is created. Logical thinking causes a change of almost all evolutionary systems and leads to a substantial acceleration of evolution.

Individual utility optimization:
Of particular importance is the variation mechanism of individual utility optimization. It obviously requires that an immaterial concept like individual utility can form at all. This was only possible by the cognitive revolution for homo sapiens. Obviously, the ability to optimize individual utility is a major evolutionary advantage overall, although in prisoner's dilemma situations it is a disadvantage. Think, for example, of climate change and similar problems.

4.12. Age [5.1], the age of market economy

The technological trait of **writing** is a storage technology for the new information type of external digital data. The invention of writing made it possible to store information externally with the help of symbols. The great qualitative leap in the documentation of debt relationships was the invention of **money**, which is nothing other than a uniform symbol for the quantitative valuation of all debt relationships. It is the precondition for the development of an efficient market economy.

Evolutionary systems

Cooperation based on written religious norm systems:
Writing was the precondition for the formation of written religious norm systems, which are often referred to as high religions. The essential function of norm systems is to enforce cooperation or the avoidance of market failure.

Cooperation based on individual contracts:
However, cooperation does not always have to result directly from general standards. It can also result from the insight of two individual partners that they are in a prisoner's dilemma and that it is therefore better for both partners to conclude a cooperation agreement. Such behavior, however, requires a high degree of cognitive ability on the part of the contracting parties and a correspondingly highly developed system of religious or governmental norms for enforcing contracts.

Regional trade:
Money in form of coins was a highly efficient catalyst for regional trade and thus also for a market economy with an efficient division of labor.

Variation mechanisms

Quantitative individual economic utility optimization:
Money is the basis for a significant improvement in the targeted variation mechanism of individual utility optimization, because with money, utility can be measured quantitatively. In the sense of K. H. Brodbeck, money appears next to human language as the second central form of socialization (Brodbeck, 2009). This is because money has not only brought a great qualitative leap in the documentation and valuation of debt relations, but also because money, above all, enables the quantification of individual utility on a uniform scale. Since then, money and individual utility optimization have permeated all areas of human life, with all the advantages and disadvantages that this entails. Individual utility measured in money becomes the determining force for wide areas of human society.

Animal and plant breeding:
Animal husbandry, arable farming and the "bookkeeping" (storage of digital data) of animal and plant productivity have provided the preconditions for animal and plant breeding as a targeted variation mechanism.

4.13. Age [5.2], the age of capitalist market economy

The technological trait of **letterpress printing** as an information duplication technology enabled the efficient production of paper money and characterized the age of the capitalist market economy.

Evolutionary systems

Cooperation based on national systems of norms:
With the development of printing, religious norms were more and more replaced by governmental norms.

National trade:
With paper money, regional trade expanded into national trade.

Variation mechanisms

Investment in real capital:
Paper money was a precondition for financing large investments and for transactions involving large amounts of money. Investment in real capital can be seen as a targeted variation mechanism in the following sense. It changes the information about the production mechanism of goods not randomly, but in a targeted way to produce more goods. In most cases, an investment in real capital and thus in the multiplication of goods is correlated with an evolutionary advantage. However, this is not always the case. Just as individual utility optimization does not lead to an optimum for all in every case, as we learn from the prisoner's dilemma, the multiplication of goods does not lead to an optimum for all, as we know from environmental and climate problems. Nevertheless, both have prevailed evolutionarily through selection mechanisms because they correlate positively with an evolutionary advantage. For a formal treatment of investment as targeted variation mechanism see (Glötzl 2023b, Chap. 16.3.4.4.)

4.14. Age [5.3], the age of global capitalist market economy

The technological trait of **electronic data processing** (EDP) is an information processing technology.

Evolutionary systems

World trade and globalization:
Electronic data processing (EDP) was the most important technological precondition for the explosive growth in international world trade and globalisation that began around 1975.

Cooperation based on international norms
With globalization, international norms have become increasingly important as a basis for international cooperation.

Variation mechanisms

Investment in human capital:
Investments in science, research and development, education and further training have received an enormous upswing with electronic data processing. In summary, these are referred to as investments in human capital. They are the basis of a rapid technological progress and are even more important for the development of mankind than investments in real capital. It can be seen as a targeted variation mechanism because it changes the information about the knowledge of effective production mechanisms of new goods not randomly, but quantitatively and qualitatively.

4.15. Age [6.1], the age of Internet society

The technological trait of the **Internet** is not only a storage technology for the new data type of networked external digital data, but at the same time a duplication technology of information, because essentially everyone has unlimited access to all data stored on the Internet. If, in Brodbeck's sense (Brodbeck, 2009), language is the first and money the second central form of socialization, then the Internet is the third form and artificial intelligence the fourth form of socialization, because Internet has permeated and AI will permeate all areas of human life, with all the advantages and disadvantages that this entails. The Internet is by no means just a continuous improvement in electronic data processing, but represents a fundamental leap in the quality of information technology, the longer-term effects of which are still completely underestimated today. Therefore the corresponding society could be called Internet society.

Evolutionary systems

Internet trade:
The Internet has an enormous impact on the economy. The essential characteristic of online trade is first the existence of electronic money and international payment systems and second that the competitive mechanism

of the market economy is dramatically intensified. Therefore, trade is extremely accelerated because it is enormously easier for buyers to select products and compare prices. As a result, people's behavior is having an increasingly rapid impact on the environment, and this impact is becoming increasingly uncontrollable.
The previous international norm systems such as human rights or world trade agreements refer solely to people and in particular to the people of the present, however, the consequences for future generations and the environment are also moving more and more into general awareness. As a consequence, there are first tentative attempts to solve these problems by new global norm systems in such a way that there is cooperation with all species in nature beyond the present.

Cooperation based on global sanctions:
Norms without sanctions are not effective in achieving cooperation. Only the Internet makes it possible to sanction the violation of international norms efficiently. For the first time, for example, international norms are linked to financial sanctions, e.g. the international climate protection agreements. Whether global norm systems with selective financial sanctions for the protection of the environment and future generations will be developed and politically enforced quickly enough and, above all, whether they will be sufficient to avoid negative feedbacks for the entire system of living nature is, from today's perspective at least, highly questionable.

Variation mechanisms

Investment in digital capital:
An investment in digital capital can be seen as a targeted variation mechanism which changes information about the quantity and quality of data storage and processing. In most cases it correlates with an evolutionary advantage in the analogue sense as investment in real or human capital.

4.16. Age [6.2], the age of AI society

The technological trait of the **artificial intelligence** is still in its infancy today. It will very quickly develop far beyond what is commonly considered artificial intelligence today (autonomous driving, expert systems, machine learning, pattern recognition, chatGPT etc.). Artificial intelligence will very quickly establish itself as a comprehensive and indispensable tool in society and bring about a dramatic qualitative change in society. Alongside language, money and the Internet, artificial intelligence can be seen as the fourth form of socialization. It is leading to a society that could be described as an AI society.
For example, translation programs based on AI are already facilitating communication on an international level. However, it can be expected that AI will ultimately lead to a new optimized synthetic world language (for details see (Glötzl 2023b, Chap. 5.18.3.)).
Artificial intelligence can be understood as a machine processing mechanism that creates new knowledge from old knowledge. Currently, artificial intelligence is methodically based on the statistical analysis of large amounts of data. This form of artificial intelligence could be referred to as artificial intelligence 1.0.
Artificial intelligence 2.0 will deliver a completely new quality. This will no longer be based on statistical analysis of large amounts of data, but will produce new information from the logical combination of existing information. We can expect this development in the future age [7].

Evolutionary systems

Stabilization based on automatic global sanctions (blockchain money):
Blockchain technology is a decentralized database management system for storing, controlling, reproducing and processing complex information. In blockchain technology “Tokens" play a key role in the description of complex rights or debt relationships. They can be regarded as tradable rights and thus represent a qualitatively new extension of money. Blockchain technology can therefore lead to win-win mechanisms in an even more efficient way than money.

Variation mechanisms

Investment in stability and resilience:
One can hope that investments in stability and resilience can ensure the survival of the human social and economic system. An important mechanism for this may be AI-based sanctions that are automatically imposed via blockchain technology and come into effect in the event of a foreseeable threat to overall utility and system stability. This will ultimately force global cooperation.

Gene manipulation:
Just as new knowledge and thus general information is created by artificial intelligence, new genetic information will be created by the targeted variation mechanism of genetic manipulation. Genetic manipulation therefore will further accelerate evolution dramatically. The effects on society and evolution as a whole are hardly predictable at present.

4.17. Age [7], the age of mankind as a single individual (cyborg) in the distant future

Although we are fully aware that it is very difficult to predict the future beyond a singular point (see Chap. 7.2), we nevertheless hypothesize a possible future. We hypothesize that the next age, whenever it comes, will be characterized by the properties of a type of information technology that combines storage technology, duplication technology, and processing technology. We assume that this technology will be characterized by **direct human-machine communication** and will lead to a merging of the real and virtual worlds.
In particular, this age will also be characterized by the development of artificial intelligence 2.0. Unlike artificial intelligence 1.0, this will no longer be based on a statistical analysis of big data, but will be able to produce new information from the logical combination of existing information. The logical combination and linking of all information stored on the Internet will result in a qualitatively completely new production of new information. The production of new information by AI 2.0 goes far beyond the stage of producing "knowledge" and can be understood as the production of comprehensive understanding.The technological preconditions for this could possibly be provided by quantum computers.

This will result in a networking of people and the environment that corresponds to the networking of the individual cells of a present-day individual. Such a single individual can be called cyborg. Just as the cells of an individual have no meaning on their own and are unable to survive on their own because they are all interdependent, human individuals will also lose their meaning. In a word: mankind as a whole will have to be regarded as a single life unit consisting of human individuals, just as the individuals today are to be regarded as a single life unit consisting of cells.

It is obvious that this will have a serious impact on the behavior of individuals, on the relationships between people and on the whole human society, culture and economy.
Just as evolution has driven cells to behave in ways that maximize utility (i.e., evolutionary fitness) for the individual as a whole, so will mankind in the age [7] be driven primarily by maximizing overall utility. However, this will then no longer be achieved by overcoming the optimization of individual utility through norms and sanctions, but through a completely new way of organizing society.

However, this does not necessarily have to happen. Because if some of the cells do not behave in terms of overall utility maximization, but in terms of individual utility optimization, then they will multiply without regard to the individual as a whole, i.e. they will behave exactly like cancer cells. Just as the development of cancer in the course of evolution cannot be ruled out, the behaviour of individuals in mankind determined by individual utility optimization cannot be ruled out either. Just as cancer usually leads to the death of the individual due to the optimization of the individual utility of the cancer cells, the optimization of the individual utility by the individuals of mankind can also lead to the extinction of mankind as a whole due to the far-reaching interconnectedness and interdependence.

5. The evolution of debt documentation and the importance of debts for cooperation mechanisms

Martin Nowak classifies the cooperation mechanisms into 5 mechanisms (Nowak, 2006): *Network selection, group selection, direct selection, indirect selection, kin selection.* We prefer to use "cooperation" instead of "selection". In 2010, however, there was a heated debate on kin selection and inclusive fitness theory as to whether kinship can lead to cooperation. We share the view of Nowak and Wilson that this is not the case (Nowak, Tarnita and Wilson 2010). In the following, we show that the concept of debt allows for a much broader classification of cooperation mechanisms.

A key characteristic of the biological traits of the ages [3.1] - [3.3] was that an event often triggered an immediate, temporally instantaneous response to that event:

- Age [3.1]: information about environment → immediate monosynaptic reflex
- Age [3.2]: information about environment (or other body parts) → immediate polysynaptic reflex (e.g. fight, imitation)
- Age [3.3]: information about complex process in the environment → processing and categorization in the limbic system → immediate complex process (emotion, tit for tat)

An essential characteristic of the following ages, on the other hand, is the possibility that an event does not have to lead to an immediate reaction, but that the reaction to this event can also occur with a significant time delay. An important example for this are debts. Debts arise from services that are initially not matched by any direct compensation. Debt formation triggers debt repayment much later. This is why the documentation of debt is so important for debts to work.

The fundamental importance of debt is that the possibility of debt formation greatly facilitates the formation of cooperation, which is a major survival advantage and a win-win mechanism for all individuals. Debts therefore are the core element for the formation and cohesion of social communities. The reason why debts facilitate the formation of cooperation is explained in detail in (Glötzl 2023b, Chap. 5.10.2.1.). The idea behind it can be explained by the following simple example.

If a tailor makes shirts and a farmer makes potatoes, then it is obviously a win-win situation for both to exchange them. But what if the tailor is hungry today and needs a month to make a shirt? Why should the farmer give him potatoes without (immediate) compensation? It helps to document the tailor's debt to the farmer with the help of a debt bill, which the tailor hands over to the farmer and which he gets back when he hands over the shirt.

The precondition for the possibility of documenting debt relationships is the existence of a storage technology for information (see *Table 5*). Therefore, the evolution of win-win mechanisms is closely related to the evolutionary theory of information.

Age	**Living being, Form**	**Technology for Win-win/ Cooperation**	**Debt**	**Win-win system, Cooperation system**
[2.1]	Single-celled	No	No	No win-win
[2.2]	„Simple“ multicellular	Cell association	No	Network win-win
[2.3]	„Higher“ multicellular	Sexual reproduction	No	Sexual win-win
[3.1]	Monosynaptic animals	Simple sensors for recognition of neighbours	No	Network cooperation
[3.2]	Polysynaptic animals	Complex sensors for recognition of group traits	No	Group cooperation
[3.3]	Limbic animals	Processing of complex information	No	Direct cooperation
[4.1]	Hominins	Storing of conscious content (brain)	2-sided debt relations	2-sided debt cooperation
[4.2]	Homo	Duplicating of conscious content (simple language)	Social debt (reputation)	Indirect cooperation
[4.3]	Homo sapiens	Counting (abstract language)	Commodity debt	Division of labor
[5.1]	Market economy	Writing	Coin money	Regional trade
[5.2]	Capitalist market economy	Printing	Paper money	National trade
[5.3]	Global capitalist market econ.	EDP	Fiat money	World Trade
[6.1]	Internet society	Internet	Electronic money	Internet trade
[6.2]	AI society	AI	Blockchain money	Stabilization from global sanctions
[7]	Cyborg	Human-machine symbiosis	No	Human-machine symbiosis

Table 5: The evolution of debts

For the formation of direct cooperation through the behavior of direct reciprocity (tit for tat, “you me so me you”) in the age [3.3], documentation of the debt relationships over a longer period of time was not yet necessary, since the reactions usually took place in immediate temporal proximity.

Long-term debt relationships were only possible with a powerful cerebrum in age [4.1], which had the ability to store complex information. Therefore, the first debt relationships did not exist before age [4.1]. They were typically characterized by 2-sides (bilateral) debt relationships ("I helped you") and led to what we call debt cooperation.

The emergence of cooperation through the mechanism of indirect reciprocity in age [4.2] is based on the formation of a high reputation for cooperators. The reputation of a cooperator can be seen as documentation of his services to many other people without direct reciprocation. Reputation is therefore, so to speak, the documentation of a social debt liability that the general public has towards a cooperator. The emergence of a high reputation of an individual requires not only the ability to store complex information, but also the ability to communicate in the form of a simple language in order to spread the knowledge of the cooperator's reputation in the community (Nowak, 2006). Indirect reciprocity therefore only became possible in the course of evolution with the development of a simple language in the age [4.2] of homo.

The next evolutionary step in the formation of debt relations was the possibility of forming commodity debts in the age [4.3] of homo sapiens. As a special form of the formation of debt relations can be considered the tradition of providing gifts, which contributed to the stabilization of human societies by consciously producing debt relations through gifts.

The next major breakthrough in the age [5.1] was the ability and method to describe or value different debts with a single symbol. This one symbol is called money. Money has subsequently itself been subject to major technological change that has had far-reaching effects on the development of mankind. The technology of money and with it the documentation of debt relationships became more and more efficient: From coin money in age [5.1], to paper money [5.2], fiat money [5.3], electronic money [6.1], to blockchain technology [6.2]. Money is the underlying cause of the enormous extent of win-win mechanisms in humans. This enormous extent of win-win mechanisms can only be found in humans and nowhere else in nature (Nowak & Highfield, 2012). Money as an efficient documentation mechanism for debt relationships is therefore the actual cause of human dominance on earth.

6. Evolution of driving forces

The dynamics of all physical and chemical processes in nature is determined by so-called driving forces. All these forces are determined by the change of the free enthalpy. The change in free enthalpy is equal to the change of enthalpy minus temperature times the change in entropy, which is called the Gibbs-Helmholtz equation. For example, for the motion of a ball in a bowl, the free enthalpy is given by the height of the bowl wall, and no entropic forces exist. The dynamics of the ball is determined by the slope of the wall, which is exactly equal to the gradient.

Interestingly, the driving forces that have emerged over the course of time can also be placed in the periodization of evolution and understood with the help of the general evolutionary theory.

We therefore proceed with the description of the natural chronology of the evolution of the driving forces resulting from the general evolutionary theory (*Table 6).*

Age	**Start years ago**	**Storage medium**	**Driving force**
[0]	4.6 x 10^9	Crystal	Self-organisation of inorganic materials along the gradient of enthalpy
[1]	4.4 x 10^9	RNA	Self-organisation of RNA molecules along the gradient of enthalpy
[2]	3.7 x 10^9	DNA	Minimization of free enthalpy along the gradient of concentration
[3]	630 000 000	Nervous system	Minimization of free enthalpy along the gradient of electrochemical potentials
[4]	6 000 000	Cerebrum	Minimization of free enthalpy along the resultants of the gradients of networked electrochemical potentials in the cerebrum by non-linear processes far away from equilibrium

[5]	5 000	External local storage	Individual monetary economic utility optimization along the resultants of individual utility gradients
[6]	10	Cloud	Attempt to achieve global overall utility maximization through individual utility optimization along the resultants of individual utility gradients with internationally sanctioned norms as constraints
[7]	future	Quantum computer	Overall utility maximization along an overall utility gradient

Table 6: Periodization of driving forces

Age [0]: In the age [0], the age of inanimate matter, the temperature has decreased. Therefore, the entropic forces have lost importance compared to the forces arising from enthalpy. This led to the transition of the inorganic earth surface from the liquid to the solid and thus enthalpy-poorer crystalline state along the gradient of enthalpy.

Age [1]: In the age [1], the age of RNA, the temperature dropped even further. Therefore, the creation of longer-chain **RNA molecules** was possible along the **gradient of enthalpy**. This was probably facilitated by the fact that the activation energy for the creation of the RNA molecules was lowered by the already existing crystal structure on the surface of inorganic matter.

Age [2]: In the age [2], the age of DNA, the behaviour of living organisms is determined by the dynamics of the corresponding proteins. These dynamics are mainly determined by **concentration gradients** (i.e. gradients of the chemical potential). These concentration gradients must always be built up or maintained by the supply of energy from outside. Life is therefore not possible without a constant supply of energy.

Age [3]: In the age [3], the age of nerve cells, electric charges became important for life. Thus, since then, dynamics is no longer determined only by concentration gradients (gradient of the chemical potential) but by the **gradient of the electrochemical potential**, which must also be built up or maintained by the supply of energy from outside.

Age [4]: The age [4] is the age of the cerebrum. The cerebrum is characterized by two properties: It is a network and requires much more energy than other organs. The reason why so much energy is required is due to the following: In the brain, information is generated locally through entropy reduction. For this to be possible, a lot of energy must be supplied so that the system is far from equilibrium and the necessary non-linear processes for entropy reduction can form. This is different from the age [2] and [3], where the dynamics are always relatively close to the equilibrium point. Roughly speaking, the dynamics of the cerebrum is determined by the **resultants of the gradients of the interconnected electrochemical potentials.** These must be kept permanently in a **state far from equilibrium** by supplying high energy.

Age [5]: In the age [5], the age of the market economy, individual agents act to optimize their economic utility, which is measured in money. They do this by exerting economic forces precisely in the direction that increases economic utility most rapidly. This is precisely the direction indicated by the gradient of utility. Since different agents do not have the same interests, they exert economic forces in different directions. The economics then moves in the direction of the resultant of these forces. This concept for describing dynamic processes in economics is called General Constrained Dynamic Models (GCD models) and was developed by E. Glötzl et al. (2019, 2023a, 2023b). Roughly speaking, the dynamics of the market economy is determined by the **resultant of utility gradients**.

As we know from the prisoner’s dilemma, the approach of all agents trying to optimize their individual utility often leads to the worst possible outcome for all. There are **two approaches** to preventing this undesirable economic outcome. These have evolved over the following ages.

Age [6]: In [6], the age of the Internet market economy, attempts are made to overcome the weaknesses of individual utility optimization by imposing additional constraints. These constraints arise, in particular, from international standards that must be fulfilled. Roughly speaking, the dynamics of the Internet market economy are determined by the **resultant of individual utility gradients constrained by international norms**.

Age [7]: In the age [7], the age of the mankind as a cyborg, the weaknesses of individual utility optimization is overcome by the maximization along the **gradient of an overall utility**.

7. The importance of targeted variation mechanisms for the rate of evolution

7.1. Overview and characteristics of targeted variation mechanisms

First let us clarify the difference between untargeted and targeted variation mechanisms. In the case of an untargeted variation, the change of information is completely random and it only becomes apparent in retrospect whether this change of information represents a fitness advantage. In the case of a targeted variation some part of the information is changed by information that has already proven to be advantageous in another evolutionary system. In this way, targeted variation mechanisms shorten evolutionary detours and avoid erroneous developments. They are therefore a very significant cause of the fact that evolution is proceeding faster and faster. Now let us give an overview about the different targeted variation mechanisms and their properties (*Table 7*).

n	Age	Start years ago	Targeted variation mechanisms
1	[0]	4.6×10^9	---
2	[1.1]	4.4×10^9	---
3	[1.2]	4.0×10^9	---
4	[2.1]	3.7×10^9	Epigenetic variations
5	[2.2]	2.1×10^9	Horizontal gene transfer
6	[2.3]	1.0×10^9	Sexual reproduction
7	[3.1]	630 000 000	Interaction, swarm formation
8	[3.2]	550 000 000	Learning of statistical relations
9	[3.3]	66 000 000	Imitation, learning of near-time causal relationships
10	[4.1]	6 000 000	Learning of time-delayed causal relationships
11	[4.2]	900 000	Teaching
12	[4.3]	60 000	Logical reasoning, individual utility optimization
13	[5.1]	5 000	Quantitative individual economic utility optimization, animal and plant breeding
14	[5.2]	500	Investment in real capital
15	[5.3]	50	Investment in human capital
16	[6.1]	10	Investment in data capital
17	[6.2]	Present	Investment in stability and resilience, gene manipulation
18	[7]	Future	Overall utility maximization

Table 7: Overview about targeted variation mechanisms

7.2. The increasing rate of evolution is the reason why we head for a singularity

Obviously, in the course of evolution, the variation mechanisms become more and more targeted. This leads to an increasing rate of evolution because they shorten evolutionary detours and avoid erroneous developments. Each beginning of a new age or subage respectively can be regarded as a milestone in evolution. If n denotes the consecutive number of a milestone and t_n the corresponding beginning, then $(t_n - t_{n+1})$ describes the duration of the respective age and $1/(t_n - t_{n+1})$ therefore describes the rate at which a new milestone occurs. In *Diagram 1* the logarithm of this rate of evolution shows a largely linear trend between the Cambrian (age [3.2], $n = 8$) and now (age [6.1], $n = 16$).

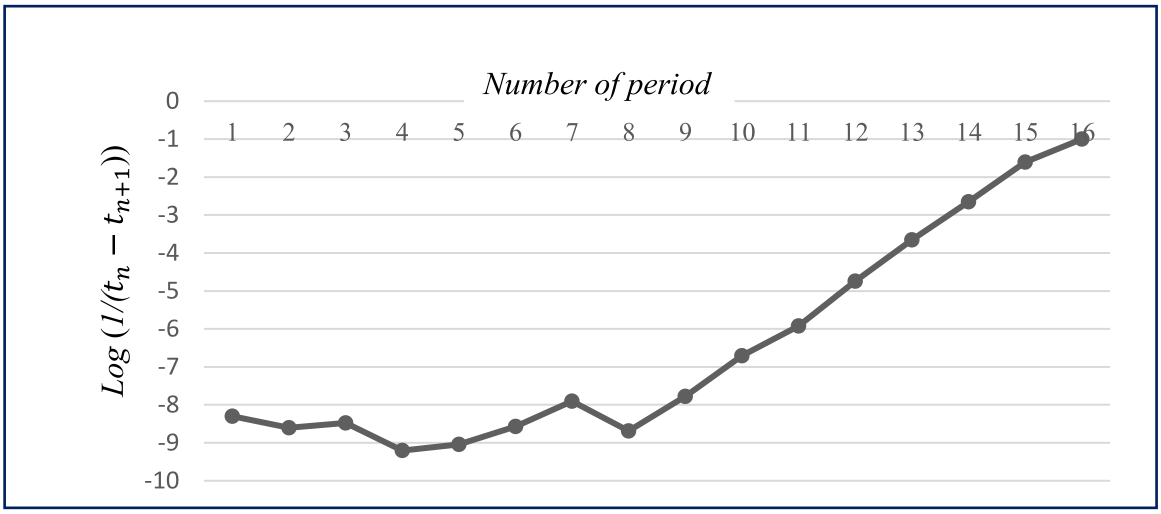

Diagram 1: Logarithm of the evolution rate

This results in a more or less constant evolution rate before the Cambrian and an exponential increase in the evolution rate from the Cambrian to the present day. Since exponential or similar growth cannot take place permanently in a finite world, there must be a singular point, a point at which the dynamics of the system change qualitatively.

Modis (2002), Panov (2005), Kurzweil (2005) and others arrive at very similar diagrams and statements. For a discussion of these results, see (A. Korotayev, 2018; A. V. Korotayev & LePoire, 2020; Solis & LePoire, 2023). However, the derivation of "canonical milestones" in general evolutionary theory that we present in this paper differs in principle from all these aforementioned papers. They are not based on a general concept of how a milestone should be defined. Therefore, there is a certain subjective arbitrariness about what should be considered a milestone. As a result, in these papers different events are often regarded as milestones. However, in this subjective way, milestones can always be defined or found to correspond exactly to the desired curve. One of the targets of the general evolutionary theory is to eliminate this subjectivity and give milestones an objective basis. A milestone of evolution in the sense of the general evolutionary theory is always exactly the appearance of a new information technology.

A central question is what happens at and after the singular point. In principle, it is not possible to answer this question based on the systems behaviour in the past. But typical behaviour near such a singular point can be (see *Diagram 2*): overshoot and collapse, overshoot and stabilization at a lower level, or stabilization at a higher level. Predicting what will actually happen at a singular point is usually quite impossible.

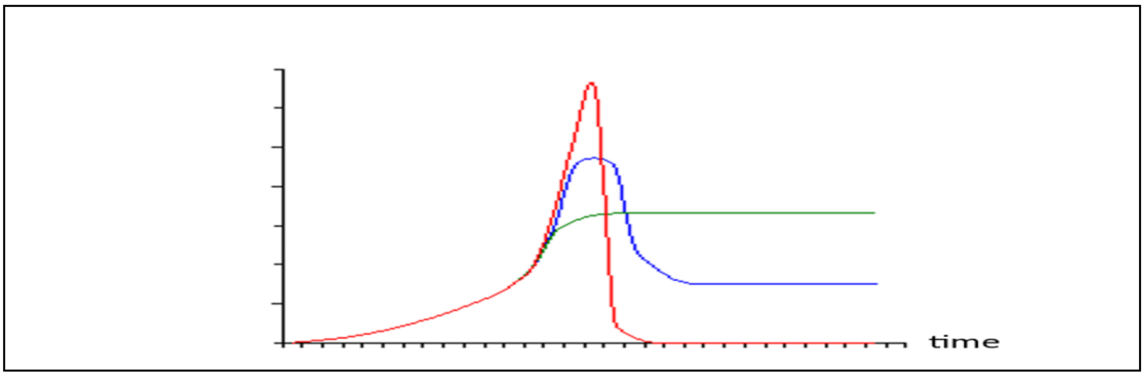

Diagram 2: Exponential growth in a finite system and its consequences at a “singular point”.

8. Discussion and comparison with other periodization models

8.1. What is the methodological key difference between the periodization model of the general evolutionary theory and other models

Methodology of most models:

1. Due to the feeling that evolution is developing faster and faster, it is assumed that the date of occurrence of evolutionary milestones or the duration of the periods defined by the milestones increases exponentially when looking into the past, see for example (Coren, 2001, 2003). This leads to linear diagrams in a log-linear coordinate system.

2. Some authors are looking for possible causes for these exponential developments:
- self-organization (Jantsch, 1980),
- escalation of logistic behavior (Coren, 2001, 2003)
- non-equilibrium steady-state transitions (NESST), *"All historical transitions between non-equilibrium steady-states follow the same pattern: an energy innovation first, structural adjustment second, and new control mechanisms third"* (Aunger, 2007),
- energy-flow (Chaisson 2001, D. J. LePoire, 2015; D. J. LePoire & Chandrankunnel, 2020; Schneider & Kay, 1994)

But even if the causes for the exponential developments were correct, periodizations cannot be stringently derived from them.

3. Rather, an attempt is made to find evolutionary milestones from other scientific disciplines such as geology, biology, anthropology, sociology or technology that fit the assumption of exponentiality or the linear diagrams. At first glance, this appears to be an objective procedure, but since the selection is subjective and not based on objective criteria, in principle a different selection could fit completely different diagrams.

Methodology of Aunger

In a largely stringent manner, Aunger (2007b) identifies a common cause for the occurrence of successive major milestones from the Big Bang to the present based on "NESSTs" (non-equilibrium steady states). He identifies 17 non-equilibrium steady states (Aunger, 2007b, Table 2). His thesis is: "All historical transitions between non-equilibrium states follow the same pattern: first an energetic innovation, then a structural adjustment and finally new control mechanisms"

Methodology of the general evolutionary theory:

1. The general theory of evolution is limited to evolutionary processes in the narrower sense, i.e. processes that are characterized by inheritance, variation and selection. This means that in these processes "something" is inherited that can change in its traits and thus in its occurring frequencies. But the processes from the Big Bang to the formation of the Earth are not characterized by this type of evolution, but by symmetry breaking due to the decreasing temperature caused by the expansion of the universe (Jantsch, 1980, p.77). The general theory is therefore essentially limited to the period from the origin of life to the present. The "something" that is inherited, varies and whose frequencies change is obviously information in its most general form.

2. The different types of information that are relevant for evolution are characterized by different storage technologies. They are subject to a logical hierarchy: Crystal, RNA, DNA, electrochemical information in nerve cells, complex contents of consciousness in the cerebrum, local external digital information (writing), delocalized external digital information (cloud), external analog information in quantum computers. The hierarchy results from the fact that the existence of the previous type of information is the prerequisite for the emergence of the subsequent type of information.

3. There are 3 basic information technologies for each type of information, which are subject to a logical hierarchy: storage technology, duplication technology, processing technology. The hierarchy in turn results from the fact that the existence of the preceding technology is the prerequisite for the emergence of the subsequent technology.

4. The times at which these technologies first appeared can be determined relatively precisely. It turns out that the timing of the technological leaps at the beginning is not subject to any simple law (see *Diagram 1*). Only from about the Cambrian Revolution onwards are these points in time subject to exponential development, because only at this point were the mechanisms of directional variation developed to such an extent that the speed of evolution was largely determined by them alone. In a sense, the mechanism of each targeted variation reduces the space of all possible variations to a smaller space of more probable variations, each with a higher evolutionary fitness. Of course, since each specific variation is stochastic, each evolutionary path can lead to different outcomes. Since the specific targeted variation mechanisms arise from the information technologies, the periodization is the same as for the information technologies.

5. The periodization by the general evolutionary theory is based on a simple logical and easily understandable common principle for all evolution. It leads not only to a periodization of living beings and forms, but also to a consistent periodization of cooperation mechanisms, debt formation and driving forces.

Therefore, compared to other methods, we consider it justified to call the classification and periodization within the general evolutionary theory the "natural" periodization of evolution on Earth. Furthermore, we hypothesize that evolution on other planets is characterized by the same principles, even if these can of course lead to very different concrete results in individual cases.

8.2. Similarities and differences in different periodization models

Periodization table):

In *Table 8* we explain the differences between the periodization table of the general evolutionary theory and other periodization tables using as examples the periodization of
a) Coren (from (Modis, 2002)),
b) Jantsch (extended framework from (D. LePoire, 2023)) ,
c) Modis (from (A. Korotayev, 2018))
d) Panov (from (A. Korotayev, 2018)
We put reasonably comparable entries in the same row. Obviously, there are a lot of unsystematic differences. For another comparison of milestones in big history for many other authors see (Aunger, 2007b; Modis, 2002).

Why crystals in the Periodisation table:

If we restrict the term evolution to processes that lead to new structures through inheritance, variation and changes in frequency, then evolution on earth only begins at the age [1.2], the age of the ribocytes. The formation of structures in the period from the Big Bang to the beginning of evolution on Earth, on the other hand, is determined by a qualitatively completely different principle. Without going into detail, these structures are created by the expansion of the universe, which leads to falling temperatures, which in turn leads to symmetry breaking and thus to new structures (Jantsch, 1980 p. 77).

We start with the age of crystals [0] because this age lies at the boundary between these two principles. Crystals (age [0]) and RNA molecules (age [1.2]) were the last ages to emerge as a result of decreasing temperature. Put simply, crystals were probably necessary as a catalyst for the formation of RNA molecules and RNA molecules were in turn the prerequisite for the autocatalytic formation of the first life-like structures in the form of ribocytes (Altman, 1990). This autocatalytic process is described by the theory of hypercycles (Eigen & Schuster, 1979). It represents the beginning of evolution on Earth.

Why we distinct between RNA and DNA:

From the perspective of information theory, RNA and DNA are fundamentally different: not only is the storage technology different (single strand versus double strand), but also the replication process. The main difference, however, is that DNA, together with the genetic code, creates the possibility of forming phenotypes. Selection no longer takes place at the genotype level as with RNA, but at the phenotype level.

Singular point:

One of our main goals in starting to analyze evolution was to understand the past in order to find answers for the future. But the analysis of the past has shown that we are heading towards a singular point in the near future (see chap. 7.2), which has also been suggested by others (A. Korotayev, 2018; Kurzweil, 2005). At a singular point, however, the structure of a dynamic system changes in unpredictable ways. Therefore, the only statement we can make with great certainty about the future on Earth is that there will occur far-reaching qualitative changes in the near future. Anything is conceivable, from the collapse of human society to a completely new organization of society in the form of a cyborg.

General evolutionary theory				**Coren**	**Jantsch**	**Modis**	**Panov**
Age	**Infor-mation type**	**Information technology**	**Living being, Form**				
[0]	Crystal	Self-organization inorganic matter	Inanimate matter				
[1.1]	RNA	Self-organization organic matter	RNA molecules				
[1.2]		Autocatalysis	Ribocytes				

[2.1]		Genetic code, phenotype	Single-celled	Procaryotes	Simple cellular	Origin of life	Origin of life
[2.2]	DNA	Cell division	„Simple“ multicellular	Eucaryotes	Complex cellular	Eucaryotes	Eucaryotes
[2.3]		Sexual reproduction	„Higher“ multicellular		Multicellular		
[3.1]		Nerve cells	Monosynaptic animals				Eucaryotes
[3.2]		Brainstem	Polysynaptic animals	Eucaryotes	Multicellular	Eucaryotes	Cambrium expolsion
					Reptiles		Reptiles
	Nervous system			Mammals		First Mammals	Mammals
						First flowers	
[3.3]		Limbic system	Limbic animals		Mammals	Primates	
				Hominoids		Humanoids	Humanoids
						Orangutan	
[4.1]		Neural network	Hominins	Hominids	Bipedal	Bipedal	Hominids
				Homo	Tools		Homo habilis
							Homo erectus
[4.2]		Simple language	Homo	Archaic Homo Sapiens	Fire/Modern Humans		Acheulian period
							Neanderthaler
				Homo sapiens sapiens		Modern humans	Homo sapiens sapiens
						Rock art	
[4.3]		Cognitive revolution	Homo sapiens	Civilisation	Modern humans	Techniques for starting fire	
						Agriculture	Neolithic revolution
					Ancient & Classical civilization	Writing	Urban revolution
[5.1]		Writing	Market economy	Writing		Democracy	
					Trade	Decimal numbers	Iron age
	External local digital data						Disinte-gration of Roman Empire
					Commercial	Printing	1st Industrial revolution
[5.2]		Letterpress	Capitalist market economy	Printing	Industrial	Industrial revolution	2nd Industrial revolution
						Modern physics	
[5.3]		EDP	Global capitalist market economy			DNA structure described	
[6.1]		Internet	Internet society				
[6.2]	Cloud	AI 1.0	AI society	Digital Computing	Information	Internet	Information revolution
[7]	Quantum computer	AI 2.0	Cyborg				

Table 8: Comparison of different periodizations

9. Conclusion

The general evolutionary theory can be seen as a comprehensive generalization and extension of Darwin's theory. It may actually be a favorite for a unified view of biological and cultural evolution and its periodization. The basic idea (see Chap. 2) is to consider not only the evolution of genetic information - as Darwin did - but the evolution of very general information, which of course includes the evolution of genetic and cultural information. It shows that evolution is characterized by the fact that new types of information have developed in leaps and bounds, each with new storage technologies, new duplication technologies and new processing technologies. This unified concept of evolution makes it possible, among other things, to

- achieve a unified view of biological and cultural evolution
- find a common natural periodization of the evolution (see Chap. 3) for
    - Living being forms (see Chap. 4)
    - Evolutionary systems and cooperation mechanisms (see Chap. 4)
    - Variation mechanisms (see Chap. 4)
    - Debt creation (see Chap. 5)
    - Driving forces (see Chap. 6)
- understand the exponential acceleration of evolution through the emergence of targeted variation mechanisms (see Chap. 7).

The general evolutionary theory develops the idea of information as an essential element for understanding evolution and its periodization in a stringent and comprehensive way. From the perspective of the general evolutionary theory, the following megatrends of evolution arise:

1. The periodization of evolution is characterized by the regular succession of new information types with the respective new storage technologies, duplication technologies and processing technologies.
2. At the beginning of evolution random variations have determined the development of evolution. However, as evolution has progressed, targeted variation mechanisms have become increasingly important. Targeted variation mechanisms are a major reason why evolution is developing faster and faster.
3. Evolution produces more and more efficient cooperation and win-win mechanisms.
4. Values and norms are a result of evolution.
5. The interplay between individual utility optimization (competition) and general utility maximization (cooperation) is of fundamental importance for the understanding of evolution.
6. We hypothesize that the evolution also on other planets basically follows the same sequence of information technologies as in the general evolutionary theory.

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