The General Evolutionary Theory as Unification of Biological and Cultural Evolution and as Basis for a Natural Periodization

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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 theory of evolution attempts to provide an answer for the period from the formation of the earth to the present and future. It was first published by E. Glötzl (2023b, 2023a). The present work is a slightly adapted, summarized version. A more extended summary can be found in (Glötzl, 2024). 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. 0), 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. 0) 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

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 →	General information
Phenotype →	Form
Mutation mechanism →	Variation mechanism
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.

3. 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 top left*).

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 1 top right*)

- 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 1 middle*) 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.

Third step:

In a 3rd essential step of extension (*Figure 1 bottom*), 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. 8.

4. 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 9), we consider it justified to call the classification and periodization

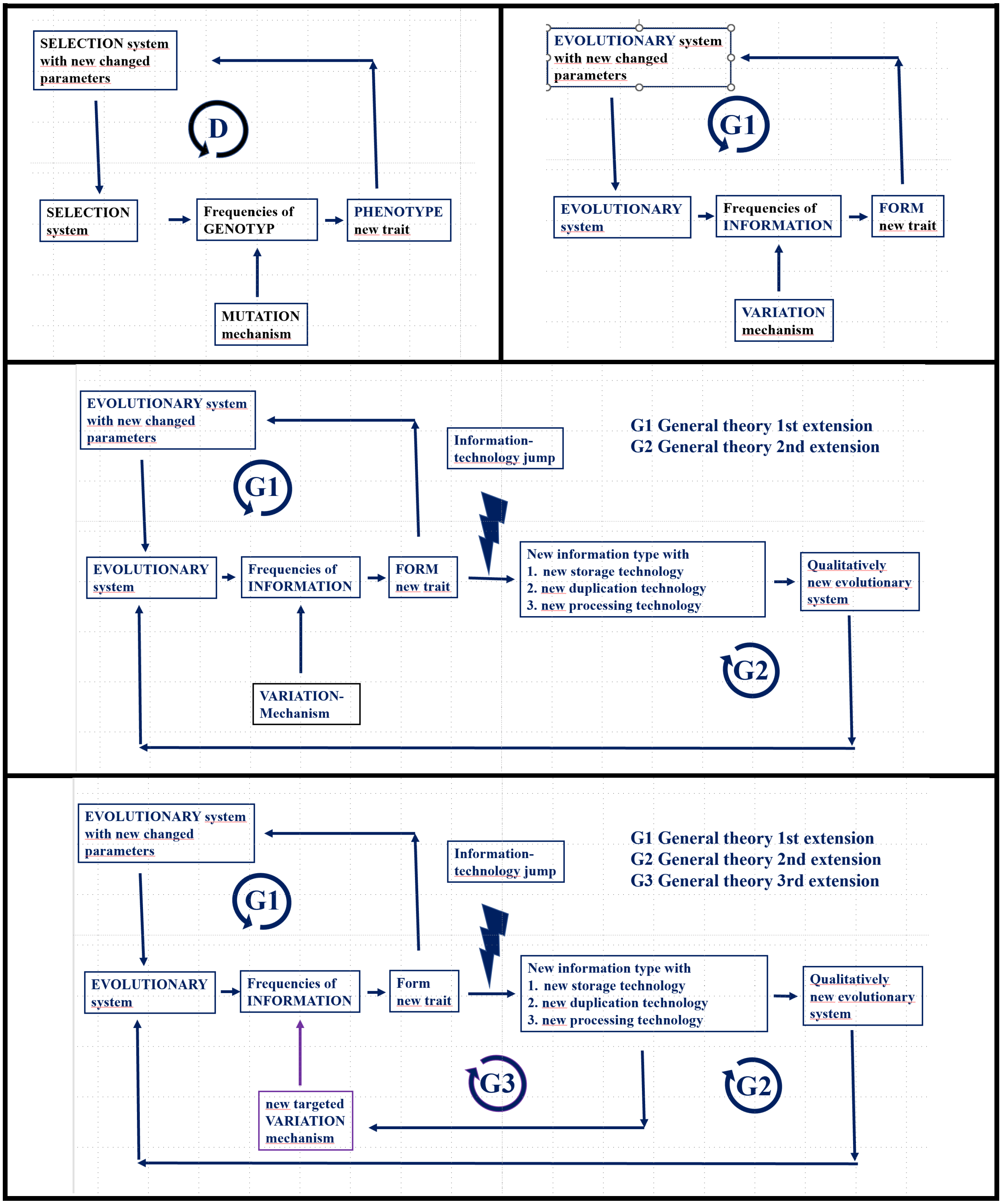

Figure 1: Darwinian theory (top left);
Extensions 1 (top right), 2 (middle), 3 (bottom)

Age	Start years ago	Information type (Storage medium) Information technology
[0]	4.6×10^9	Crystal
[0]	$4{,}6\ 10^9$	Self-organization of inorganic matter
[1]	4.4×10^9	RNA
[1.1]	$4{,}4\ 10^9$	Self-organization of organic matter
[1.2]	$4{,}0\ 10^9$	Autocatalysis (Stone, 2013)
[2]	3.7×10^9	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 (Sánchez-Baracaldo et al., 2017; Veyrieras, 2019)
[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 (Podbregar, 2019; Rigos, 2008)
[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 sub-ages of the natural 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*).

5. 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*.

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.

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

Martin Nowak classifies the cooperation mechanisms into five 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.

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

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.

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]. In this age 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.

7. 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 confine ourselves to describing the natural chronology of the development of the driving forces resulting from the general theory of evolution in *Table 6*.

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

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

Age	Living being, Form	Technology for Win-win/ Cooperation	Debt and dept documentation	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

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*).

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. *Diagram 1* shows that the logarithm of the evolutionary rate remains more or less constant until the Cambrian (age [3.2], n = 8), but then increases largely linearly until today (age [6.1], n = 16).

This means a more or less constant evolutionary rate before the Cambrian and an exponential increase in the evolutionary 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.

9. Discussion and comparison with other periodization models

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

Age	Start years ago	Storage medium	Driving force
[0]	4.6×10^9	Crystal	Self-organisation of inorganic materials along the gradient of enthalpy
[1]	4.4×10^9	RNA	Self-organisation of RNA molecules along the gradient of enthalpy
[2]	3.7×10^9	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

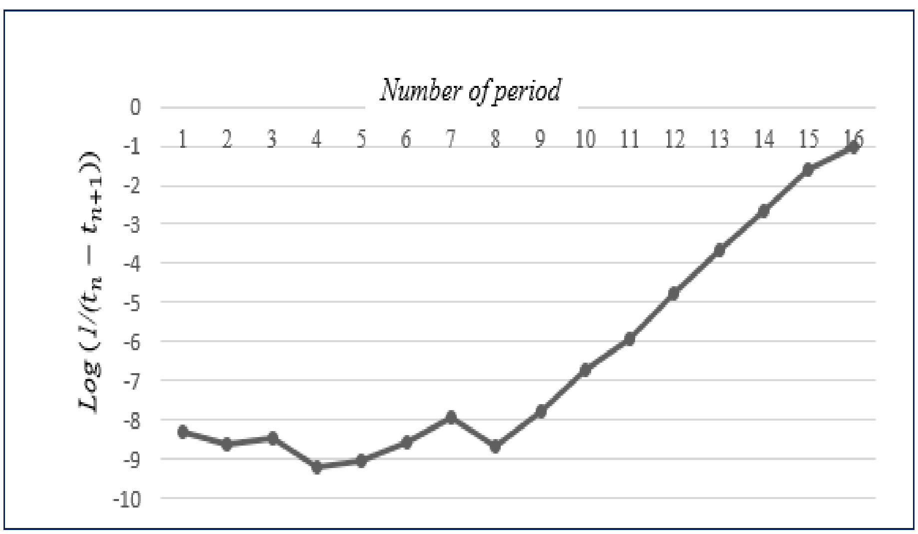

Diagram 1: Logarithm of the evolution rate

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.

Similarities and differences in different periodization models

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 begin 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

n	Age	Start years ago	Targeted variation mechanisms
1	[0]	4.6 x 10^9	---
2	[1.1]	4.4 x 10^9	---
3	[1.2]	4.0 x 10^9	---
4	[2.1]	3.7 x 10^9	Epigenetic variations
5	[2.2]	2.1 x 10^9	Horizontal gene transfer
6	[2.3]	1.0 x 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

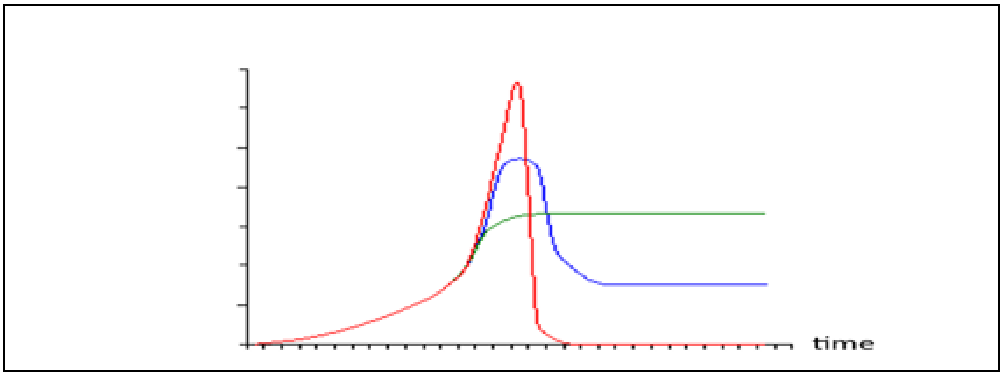

Diagram 2: Exponential growth in a finite system and its consequences at a "singular point".

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. 0), 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.

10. 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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