IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 12 Issue 05, May 2025
ISSN (Online) 2348 – 7968 | Impact Factor – 6.72
www.ijiset.com

Evolution: From Darwin-Wallace to the Expanded SyNaDE-Model

Ulrich Kutschera

AK Evolutionsbiologie, 79104 Freiburg i. Br., Germany & I-Cultiver, Inc., San Francisco CA 94130, USA
E-mail: kutscherau@gmail.com

Abstract
Biological Evolution is the process through which variable populations of organisms change over time and space, as individuals gradually diverge from one another during the course of subsequent generations. The fact that evolution has occurred (and continues to take place) is documented in the fossil record, which shows that the earliest marine a-sexual prokaryotic microbes are about 3500 million years (my) old. After symbiogenesis ca. 1800 my ago, eukaryotic organisms, such as simple animals, evolved, which are characterized by reproduction via gamete (sperm-egg)-fusion (eukaryotic sex); complex forms only emerged after the Cambrian explosion ca. 539 my ago. Organismic evolution via universal common descent is also attested to by studies of comparative anatomy and molecular structure (amino acid-, or DNA-sequences of homologous proteins or genes in various species). The evolutionary history of life on Earth, as envisioned by Darwin and Wallace, can be depicted as a complex branching tree, a general phylogeny, showing the relationships of all species to one another, and the course of their development (for instance, chimpanzees vs. humans). Here, I document that Symbiogenesis-Sex, Natural selection and the Dynamic Earth (Plate tectonics, volcanism, climate change) are key processes that gave rise to the biodiversity on our ever-changing Blue planet (Expanded SyNaDE-model of macroevolution). In addition, the "Ingroup/Outgroup" (or "Us-vs.-Them")-Principle is outlined, with reference to hominid evolution.
Keywords: *Evolution, Common descent, Darwin, Extinction, Natural selection, Species, Symbiogenesis, SyNaDE-model*

Introduction

In September 2016, the author submitted an invited manuscript with three Figures to the "Content Project Managers" of a major Multi-Author-Series entitled "Reference Modules in Life Sciences", published by Elsevier Ltd.-Oxford, U.K. After peer-review and revision, this 2017-article, a concise summary about "Evolution" from an organismic perspective, was published [1]. In a second 2017-paper on "Endosymbiosis and cell evolution", some aspects of the former article were described in more detail [2]. One key topic of these Reviews was a short summary of the "SyNaDE" (Symbiogenesis-Natural Selection-Dynamic Earth)-model of macroevolution. This theory was proposed 2009 in a contribution on the life and work of Charles Darwin (1809–1882) [3], and treated in more detail from a bio-geological perspective in a "Wallace"-paper published two years later [4].

Over the past decade, many new facts, data and insights appeared in the scientific literature dealing with chemical and biological evolution (see the textbook of U. Kutschera 2025, ref. [5]). Accordingly, an update of this scientific article [1] that covers a general topic of the Life Sciences, was requested by students and colleagues.
In this supplemented version of the illustrated text, I summarize our current views of the key processes that generated, starting with 3500 million-year-old simple archaic bacteria-like forms of life, the extant biodiversity on our dynamic Earth [4]. Moreover, the "Ingroup/Outgroup" (or "Us-versus-Them")-concept in evolving populations of primates (hominids) is described and depicted. In a *Glossary* added to the main text, key terms are explained, so that non-specialists can better understand the complex biological facts, as detailed below.

This article is dedicated to the memory of the Ukrainian/American biologist Theodosius Dobzhansky (1900–1975), whodied 50 years ago. Dobzhansky was one of the "architects" of the "Synthetic theory of biological evolution" of the 1940s. In 1973, he coined the famous phrase: "Nothing in biology makes sense except in the light of evolution" [6] – a truism that summarizes the core principle of the *Biomedical Sciences* in a concise way.

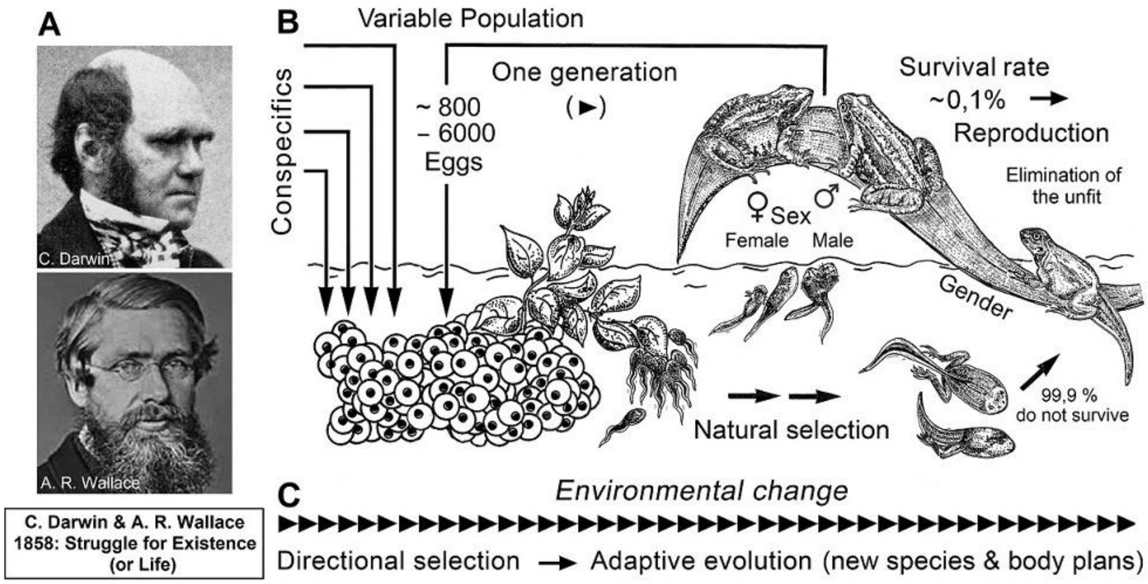

Fig. 1 Populations of organisms and the Darwin-Wallace principle of natural selection (A). Water frogs (*Rana* sp.) produce thousands of fertilized eggs per pair (sexual reproduction, variable offspring with de novo-mutations) (B). Due to limited resources there is a struggle for life, consisting of competition and cooperation among developing (juvenile) and adult male/female individuals within natural populations (gender-ratio ca. 2/3 male). Over hundreds of subsequent generations, gradual changes in environmental conditions can cause adaptive phenotypic evolution by directional natural selection (C) (adapted from ref. [5]).

Descent with modification: Darwinian fitness

Biological evolution, defined by Charles Darwin (Fig. 1A) in his *Origin of Species* (1859; 6th ed. 1872) [3, 5] as "descent with modification", is attributable to the nature of living beings. Organisms are self-reproducing, open systems that operate due to instructions (i.e., genetic information) encoded in their DNA-based genomes. During the course of reproduction, parental genomes are replicated to produce new copies for the offspring (Fig. 1 B). However, replication is not perfect, and heritable mutations continuously introduce genetic novelties. Furthermore, sexual reproduction entails the re-shuffling of chromosomes into different combinations, so individuals acquire, via meiotic re-combination, variant genomes, thus giving them different traits (or trait values). Populations inhabit ecosystems that afford various opportunities for obtaining the limited resources they need (living and brooding space, food, etc.). Each organism, with its unique combination of traits, has a specific inborn ability to exploit those resources, i.e., to optimize reproductive success (Darwinian fitness) in a particular ecological niche. Those that leave the most offspring have, by definition, the highest fitness, and thus are most successful in passing on their genotypes to the next generation. Thus, populations of organisms in which there is variation, reproduction generating a surplus of descendants, and heredity can evolve by natural selection. As Darwin and Alfred Russell Wallace (1823–1913) (Fig. 1A) recognized in 1858, natural selection is the central process governing biological evolution in groups of animals and plants. However, sexual selection, and other processes (symbiogenesis, geographic isolation of sub-populations via Plate tectonic etc.) may also play an important part.

The Modern Theory: An expanded synthesis

Some major features of biological evolution, and especially the centrality of natural selection, became clear from Darwin's great original and theoretical work [6,7]. However, it was the German zoologist August Weismann (1834–1914) who discovered that acquired characteristics are not heritable, as Darwin (but not Wallace) had assumed, and that sexual reproduction via the fusion of gametes (egg plus sperm creates a zygote from which offspring can develop) is the major cause of variability. The basic tenets of this Neo-Darwinian theory ("Weismannism"), that was also supported by the 1889-book of Wallace, were summarized by the German biologist in a major monograph published in 1904/1913 [5].

Synthetic Theory. Nevertheless, a consensus on the cellular and molecular processes only emerged in the early decades of the 20th century. By about 1940, it was possible to outline a modern, synthetic theory combining the essential discoveries of Mendelian genetics with a mathematical analysis of genes in populations as outlined by Ronald A. Fisher (1890–1962), Sewall Wright (1889–1988) and John B.S. Haldane (1892–1964), and with the observations of taxonomists and field naturalists (Ernst Mayr, 1904–2005; Theodosius Dobzhansky, 1900–1975; George L. Stebbins, 1906–2000, George G. Simpson,1902–1984 and Bernhard Rensch,1900–1990). Since that time, some tenets of this model of evolution have been challanged, and an enormous number of new facts and sub-theories have been added. However, the basic "Darwin-Wallace"-concept (Fig.1) remains intact – with major modifications: Our modern theory of biological evolution is an expanded synthesis [8].

Individuals vs. Populations. Evolution is a population phenomenon (Fig. 1 B, C). Individuals grow, reproduce, and die, whereas populations can evolve. Studies of morphological, genetic, and biochemical features have shown that expanding natural populations harbour enormous variation, and this variability is the basis for biological evolution. It acts as a kind of "genetic insurance", or a "biological buffer" that allows the population to maintain itself by adapting to future environmental changes and perils, since the Earth is dynamic so that, over thousands of years, new habitats are generated and destroyed, respectively. In addition, plants and animals have always been under attack by a variety of pathogenic microbes (viruses, bacteria, fungi etc.). Most populations are highly polymorphic. The classic observations by T. Dobzhansky of the 1930s on fruit flies demonstrated that populations carry many chromosome types, and that the frequencies of these chromosomal variants vary geographically, reflecting subtle adaptations to different environments (6). The mere re-combination of allelic differences already present in a natural population (ignoring further variations created by heritable mutations) is adequate to produce considerable novelty and thus constitutes the raw material for directional natural selection, a process that occurs, over numerous generations, in response to changing environmental conditions (Fig. 1 C). In contrast, stabilizing natural selection (the weeding out of the unfit) maintains a living population, under constant environmental conditions, in its adapted state. Studies on human populations revealed that genetic variability is attributable to re-combination via sexual reproduction and heritable germ-line mutations (ca. 50 : 50 % of variation each).

Meiosis causes mutagenesis. In addition to creating variable offspring, the production of sperm and egg cells in the testes / ovaria via meiotic recombination is the source of de novo-mutations. In all organisms investigated so far (from yeast to humans), recombination is initiated by many DNA double-strand breaks of which only few result in the formation of chromosomal crossing overs. Due to error-prone repair-mechanisms, mutagenesis occurs in the human germ line, leading to new, heritable mutations in 25 % of sperm and 1/12 of the egg cells [9]. As a result, sexual reproduction causes a substantial burden of genetic diseases in new-borns (40 % higher chance for certain cancers, anaemia, heart defects, neurological disorders etc.). Accordingly, the term "Meiosis-sex-Dilemma" has been coined to denote these effects [5, 9].

Cells versus complex organisms. Biological evolution, which originated with the earliest a-sexual bacteria, can be divided into several phases (Fig. 2). At the cellular level, ancient primary endosymbiotic events (symbiogenesis, i.e., the fusion of certain prokaryotes, ca. 1800 million years ago) gave rise to eukaryotic cells with organelles (mitochondria, plastids). These nucleus-containing cells have the capability to evolve into complex, "sexy" multicellular organisms, such as animals, fungi and plants. According to the "ROS (Reactive Oxygen Species)-Sex-Model", bi-parental (sexual) reproduction was established ca. 1200 my ago. It was caused by the development of oxygen-consuming/ATP-producing-ROS-releasing intracellular mitochondria in the earliest, marine eukaryotic cells that resulted in O_2-Stress, and DNA-repair-mechanisms [10]. Later, secondary endosymbioses were responsible for the evolution of the marine phytoplankton (ca. 250 my ago).

Evolution beyond the species level

Most people accept adaptation of species to new environments, according to the Darwin-Wallace-concept (Fig.1). However, they are skeptical when it comes to the development of novel body plans during the history of life, as documented in the fossil record. In this section, these key issues of evolutionary biology are discussed.

Micro- vs. *Macroevolution*. The term *Microevolution* refers to adaptations, inclusive of speciation, which denotes the process by which a single species (or population) divides into two or more such units (Fig. 3). The evolution of humans and chimpanzees from a common ancestor that existed ca. 7 my ago in Africa (*Sahelanthropus*) is a well-documented speciation process. Both *Homo sapiens* and *Pan troglodytes*-populations, which share ca. 99 % of their protein-coding genes, live in social groups wherein individuals cooperate. These territorial “Ingroups” (Us) are frequently in war-like conflict with competing “Outgroups” (Them), so that primates (as well as other organisms) may be characterized as ”altruistic-egoistic opportunists” (Figs. 3, 4). Anatomically modern humans developed ca. ¼ my ago in Africa. Subsequently, several sub-populations moved “Out-of-Africa” to colonize all continents, while evolving into the five “Human Races” (Continental populations) known today (i.e., Africans, Asians, Caucasians, American Indians, Oceanians). In primates, cultural evolution, i.e., the non-genetic transfer of knowledge, supplements biological phylogenetic development. This topic is beyond the scope of the present article.

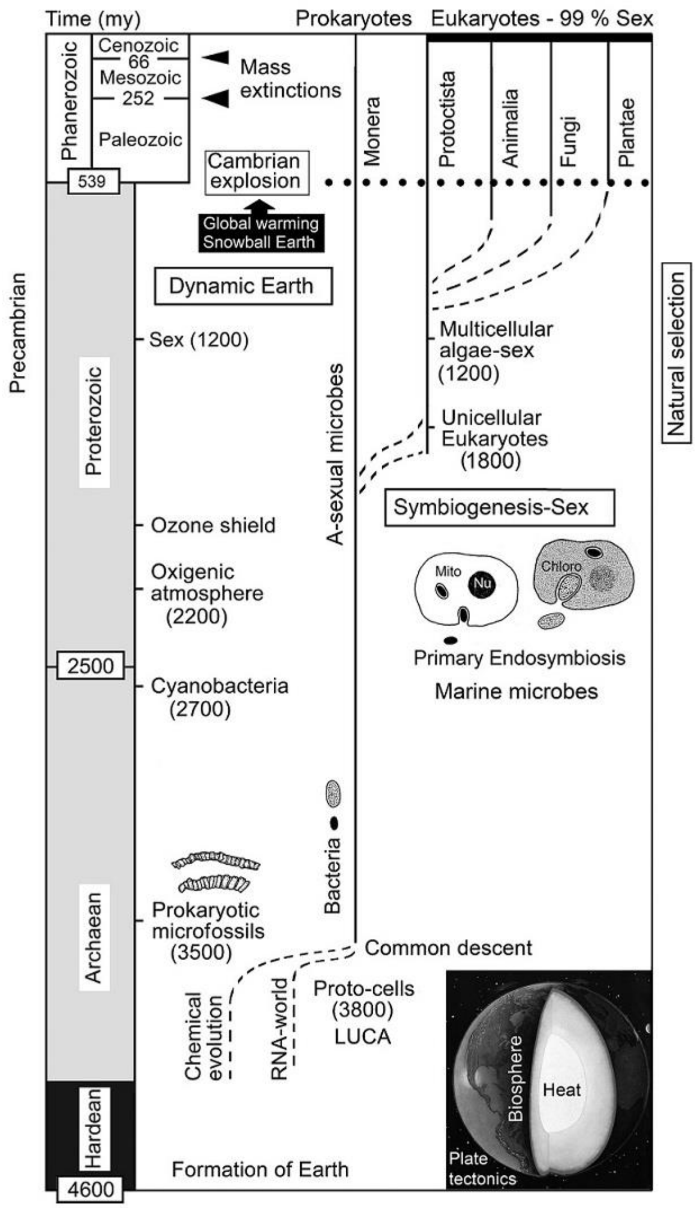

Fig. 2 Evolution of life on Earth. Ancient Proto-cells (LUCA) gave rise to the earliest prokaryotic cells (bacteria-like microfossils) that are about 3500 million years (my) old. Today, the descendants of these archaic microbes represent the dominant groups of organisms on Earth (Kingdom 1: Bacteria, syn. Monera). Symbiogenesis (primary endosymbiosis) gave rise to “sexy” eukaryotic cells, which evolved, via unicellular progenitors, into members of the Kingdoms 2 to 5: Protoctista (amoebae, algae, phytoplankton etc.), Animalia (animals), Fungi (mushrooms etc.), and Plantae (plants). Directional natural selection, driven by changes in environmental conditions via the dynamic Earth (Plate tectonics, volcanism, “Snowball Earth”-events/global warming, climate change etc.), caused biological evolution, associated with extinctions, in all five Kingdoms of Life (Expanded SyNaDE-model). LUCA = Last Universal Common Ancestor; Chloro = Chloroplast, Mito = Mitochondrion; Nu = Nucleus (adapted from ref. [5]).

Macroevolution refers to the larger changes observed over much longer geologic time intervals (thousands to millions of generations), as organisms of quite different body plans gradually develop. Examples are the "Cambrian Explosion" ca. 540 my ago, or the transition of theropod dinosaurs to birds during the Mesozoic, ca.150 my ago. As Figures 2 and 3 illustrate, major catastrophic events, such as severe climate change due to variability in sun activity, "Snowball-Earth"-episodes followed by Global warming, volcanism caused by the Dynamic Earth etc. have triggered these slow transformations of body plans. These macro-evolutionary transitions occurred in large, variable populations over millions of years of Earth's history – often accompanied by mass extinctions of numerous "out-dated" species. It should be noted that primary and secondary endosymbiotic cell-fusion events (symbiogenesis), which lead to novel uni-cellular body plans (mitochondria- und chloroplast-containing eucytes), have been described as examples for macroevolution at the level of microbes [5].

Species definitions. There is a long, ongoing discussion as to what species are and how we can define them. The biological species concept (BSC) of E. Mayr [11] states that a species is a group of populations that are actually or potentially capable of interbreeding with one another. This definition is only relevant to bi-sexually reproducing organisms, such as humans, water frogs and other vertebrates (Fig. 1 A,B), but largely meaningless for those that reproduce a-sexually. Such forms of life (bacteria etc., see Fig. 2) are related only by cell divisions, augmented by occasional lateral gene transfer. The BSC has been applied to most groups of animals as well as plants. However, members of the Kingdom Plantae are able to reproduce in more plastic ways and to hybridize with one another [12]. The BSC has been challenged by the phylogenetic species concept, which says, essentially, that a species shall be considered a distinct branch of a phylogenetic tree that can be distinguished morphologically or genetically. We know that 'species' by any conception have diverged from one another in the past and continue to do so, i.e., biological evolution is a fact of nature.

Modes of speciation

As described by E. Mayr [11] and others, speciation probably occurs primarily through geographic isolation. Two populations are said to be sympatric if their ranges overlap and allopatric if they do not. Speciation in many well-documented instances has evidently occurred when one sub-population of a species becomes isolated from the rest, often due to geological events (Dynamic Earth). During the long time of its isolation via the rise of new mountain ranges etc., it acquires differences that result in reproductive isolation once the two sub-populations again become sympatric. Reproductive isolating mechanisms may entail ecological factors, such as occupying slightly different habitats, so prospective mates do not come into contact; temporal factors, such as breeding at different times; and physical barriers to reproduction such as chromosomal re-arrangements, incompatibility between haploid sperm and eggs, or failure of hybrid embryos to develop. Intense speciation events are obvious in archipelagos; the ground finches (Geospizinae) of the Galapagos Islands or the honeycreepers (Drepanididae) of the Hawaiian Islands show how one original population has diverged in the course of several million years into a variety of species, occupying different ecological niches, as sub-populations became isolated from one another on different islands [5, 6].

Plant Evolution. While geographic (allopatric) speciation may be a common process in animals, many plants have evolved through genetic events that may occur sympatrically, via hybridisation and subsequent polyploidisation, i.e., the generation of tetra- or hexaploid conditions, as a result of the combination of two parental diploid nuclei. In addition to the universal Darwin-Wallace-Mechanism, plant evolution has been explained by introgressive hybridization, in which related species hybridize and one or more chromosomes of one parent species becomes incorporated into the genome of the other, eventually resulting in a third species with features derived from both parents [5,6,12].

Genetic Drift. Mathematical analyses of the behavior of genes in populations has shown how the frequencies of alleles change by heritable mutations and/or by various regimes of selection. The rate at which these changes occur depends on the size of the population, i.e., in small populations genetic changes occur rapidly in a way not determined by directional natural selection. This phenomenon, called *genetic drift*, may be important in speciation [13]. The individuals that become isolated in the first place may themselves have genotypes different from the average genotype of the much larger parent population (founder effect on islands; the rapid evolution of the German "Jesus"- cockroach etc.) [5].

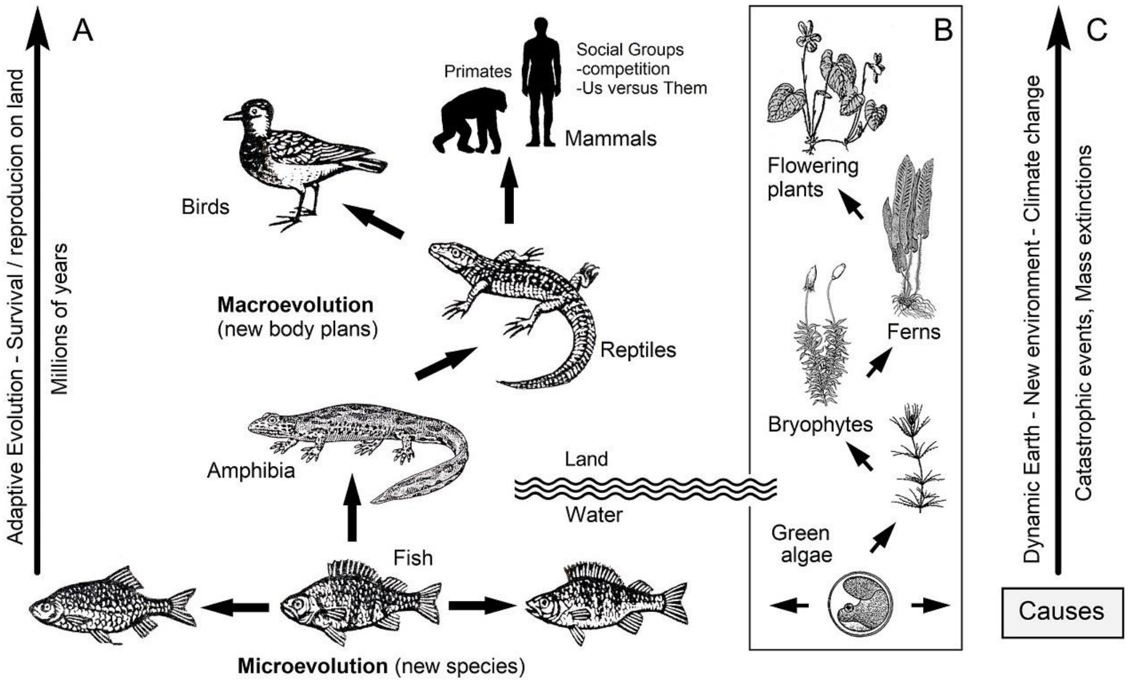

Fig. 3 Micro- versus Macroevolution in animals and plants. Microevolution leads to new varieties and species characterized by essentially the same body shape, whereas macroevolution denotes major phylogenetic transitions, or the accumulative development of new body plans over millions of generations. The depicted extant (bi-sexual) organisms represent the basic body form of the fossil ancestors of the corresponding taxa. Macro-evolutionary transitions were often caused by major environmental changes or upheavals, caused by the Dynamic Earth (Plate tectonics, volcanism, major climate change, associated with cooling-warming episodes). African Primates (mammals) are characterized by living in social male/female “Ingroups” that compete with “Outgroups” (strangers of the same species) (adapted from ref. [5]).

Common descent, mass extinctions and Evo-Devo

Universal common descent, as postulated by Darwin, Wallace and others, is a well-supported concept that accounts for the unity, as well as the diversity of all forms of life on Earth, from prokaryotic microbes (bacteria) to eukaryotic “super-organisms” (humans and other vertebrates). Animals harbour symbiotic microbes in their gut, and plants are associated with symbiotic fungi (root system), as well as numerous epiphytic bacteria that cover the entire body of the green organism. Hence, most Eukaryotes are *holobionts*, also called “superorganisms” [5]. Accordingly, symbiotic microorganisms, such as gut microbes, have *co-evolved* with their corresponding host organism. For instance, humans are occupied by ca. 1,3 x more bacteria than somatic body cells, that define “Us” in contrast to our micro-biotic symbionts (“Them”).

LUCA. The facts that cells originate from mother cells, heritable material (DNA) from pre-existing genes that are transferred via sexual reproduction to the next generation (Figs. 1, 2), and the occurrence of five major classes of universal biomolecules are proof for common descent (Fig. 4). In addition, it should be noted that oxygen-consuming-ATP-producing mitochondria (descendants of once free-living alpha-proteobacteria) are ca. 1800 my-year-old “universal” organelles of all eukaryotic cells, from yeast to humans. As a result, a Last Universal Common Ancestor (LUCA) must have existed ca. 3800 my ago, from which, via macro-evolutionary processes, all extant (and extinct) organisms descended, with major modifications (Five Kingdoms, see Figs. 2 and 4).

Extinction. The fossil record reveals three major patterns in biological evolution of macro-organisms (animals, plants): speciation, extinction, and phyletic evolution. Speciation has already been described. *Extinction* is clearly a major feature of evolution. Although a few species have apparently persisted for very long times in relatively stable environments, such as the depths of the ocean, most species of animals and plants (ca. 99 %) have appeared in the fossil record, persisted for periods on the order of one to ca. 20 million years, and then have gone extinct. Large-scale extinction events are not documented for small, unicellular ("primitive") microorganisms, forms of life that have persisted over the past 3500 my of Earth's history. Apparently, multicellular macro-organisms are more "sensitive" towards major, catastrophic environmental perturbations. Five major mass extinctions, caused by geological or extra-terrestrial events (Dynamic Earth/ Plate Tectonics-volcanism, major climate anomalies, bolide impacts etc.), are documented. During these "disturbing" episodes, extreme phenotypes have survived that have given rise to new evolutionary lineages and body plans (for instance, the extinction of the dinosaurs by the end of the Mesozoic ca. 66 my ago, and the subsequent rise, plus macro-evolutionary diversification, of mammals that finally led to the emergence of our species) (Figs. 1, 3, 4).

Phyletic evolution. This term refers to a gradual change in morphology in a certain direction; for instance, human evolution, which has entailed a gradual increase in height and cranial capacity. However, phyletic evolution may be illusory and phylogenetic development is more properly described as *punctuated equilibrium*. A species generally endures with little or no change until it becomes extinct, but occasional instances of speciation occur within a few million years, so it may appear that a single species has gradually changed. Instances of apparent phyletic evolution and punctuated equilibrium are both documented in the fossil record.

Homeotic Genes. In accordance with the classical "Darwin-Wallace-principle" (Fig. 1), the synthetic theory of 1950 pictured evolution as being driven largely by natural selection of alleles with small effects, over relatively long times. This viewpoint has been challenged by champions of punctuated equilibrium with rapid speciation and by proposals that more drastic genetic events might be responsible for quite dramatic changes in morphology. It is clear that small genetic effects can account for the large morphological changes observed in fossil series. Furthermore, speciation that appears to be rapid on the geological time scale may actually require tens of thousands of years, a period perfectly consistent with small, slow genetic events. On the other hand, studies of developmental genetics have revealed so-called *homeotic genes* that govern major morphological changes. The combination of developmental biology with the evolutionary sciences (Evo-Devo) has revealed modes of rapid evolutionary change that results from modifications in these regulatory genes [13,14].

Evolutionary biology: a system of theories and the SyNaDE-Model

The architects of the synthetic theory and founders of the modern evolutionary sciences, T. Dobzhansky, E. Mayr and others, developed their concepts on the basis of Darwin's and Wallace's classical view of biodiversity, according to which animals and plants (i.e., eukaryotes) are the dominant organisms on a more or less static Earth. However, today it is clear that prokaryotes (bacteria, cyanobacteria) account for more than 50 % of the protoplasmic biomass, and eukaryotic microbes (amoebae, algae, marine phytoplankton etc.) add at least another 30 % to this equation. As a result, over a time period of ca. 3000 my, biological evolution has been a phenomenon that has predominantly taken place at the level of single cells (Fig. 2) – organisms that have served as model systems for the analysis of the origin of sex, a key process in the history of complex life on Earth [14].

Expanded SyNaDE-model. Bacteria influence, as symbionts as well as pathogens, the evolution of animals and plants. Hence, Symbiogenesis (endosymbiotic events), directional Natural selection (the elimination of less adapted varieties), and the Dynamic Earth (Plate tectonics) are key processes that have caused and continue to drive the evolutionary development in living, variable populations of organisms (Figs. 1, 2). This "SyNaDE-model" of macroevolution has been described in the peer-reviewed literature [1–4]. The recent discovery that sex (i.e., bi-parental reproduction via gamete fusion), a process that developed as a consequence of primary endosymbiosis at least 1200 my ago (explained by the "ROS-Sex-hypothesis") represents the dominant mode of creating progeny in ca. 99 % of eukaryotes, led to the *Expanded SyNaDE*-theory. According to this concept, *Symbiogenesis* & *sex*, *Natural selection*, and the *Dynamic Earth* (Plate tectonics / volcanism, inclusive major, variable sun activity-driven climate changes, such as the "Snowball-Earth-Global warming-episode", and bolide-impacts) are the key processes that have driven, and still cause, biological evolution [5].
In general, populations of organisms, the "units of evolution", are steadily challenged by changes in the environmental conditions. The corresponding collectives of living beings either respond with adaptation/diversification, and thus continue to exist in modified forms, or become extinct (Fig. 3). Finally, it should be remembered that sex causes not only variability, but also heritable diseases (mutagenic effect of meiotic recombination) [9], a recent key insight of modern biology.

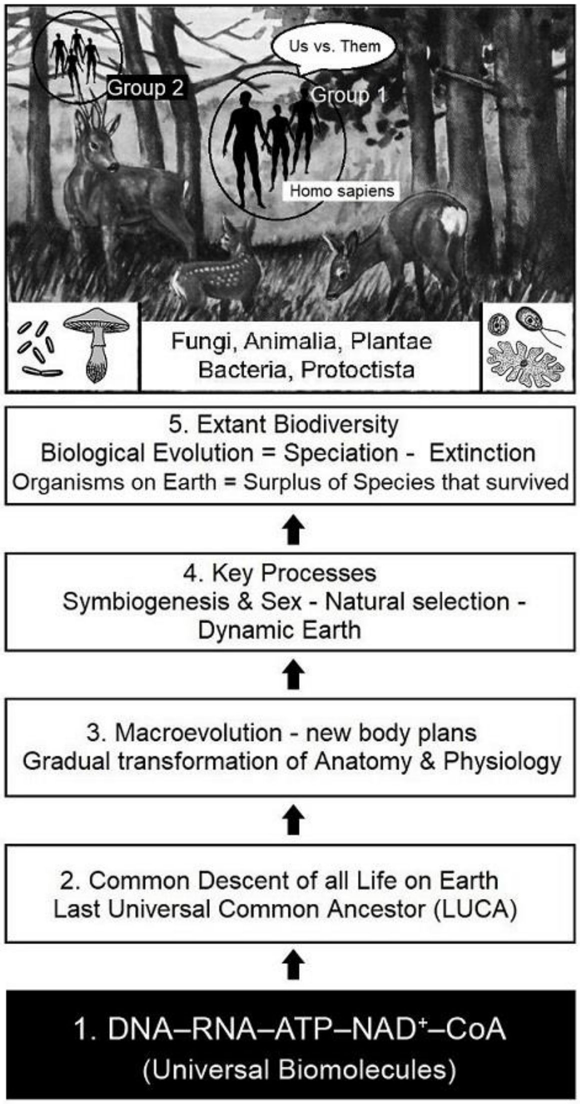

Fig. 4 Common descent, macroevolution and biodiversity on Earth. The unity of cellular biochemistry (1.) supports the concept of LUCA (2.). As a result, macro-evolutionary transitions occurred over millions of years via descent with modifications (3.), which was driven by three key processes: Symbiogenesis-sex, directional Natural selection, and the Dynamic Earth (4.). Accordingly, all extant (and extinct) organisms are genealogically related (5.). Primates, such as humans (bio-species *Homo sapiens*), form social "Ingroups" that are in competition with "Outgroups" (strangers; Us-vs.-Them-Principle, illustrated in European "Out-of-Africa"-subpopulations 1 & 2). ATP = Adenosine triphosphate, CoA = Coenzyme A, DNA = Deoxyribonucleic acid, NAD+ = Nicotinamide adenine dinucleotide, RNA = Ribonucleic acid (adapted from ref. [5]).

What works-Continues and Design-Errors. Since most sexual organisms are "altruistic & egoistic opportunists" that have to carry a severe "disease burden" per generation (meiosis-sex-dilemma), it is obvious that biological evolution occurred, and still takes place, according to the following "blind" principle: "What works-continues / what is less effective is eliminated via natural selection". It follows that evolution cannot "create" perfect organisms, and is not driven by an "inborn" tendency toward increasing information and complexity [15], as Darwin [3] and others had assumed. Rather, only more-or-less deficient, evolved "compromises of nature" have been discovered [8] – characterized by numerous "design errors", such as:
The vast overproduction of offspring per parent, doomed to go extinct (Fig. 1B); the poor DNA-repair mechanisms responsible for disease-causing mutations during sexual reproduction [9]; the production of destructive-mutagenic ROS during mitochondrial respiration, the five catastrophic mass extinctions during the phanerozoic [5] etc.
Moreover, the well-documented male-driven aggression in chimpanzees and humans, leading to lethal intergroup violence and wars ("Us-versus-Them"-principle) (Figs. 3, 4) is proof against the assumption of an "Intelligent Designer", as

described in the Bible and other religious books. Darwin and Wallace (Fig. 1 A) were well aware of this "cruelty in nature" and argued, accordingly, in an agnostic-atheistic style when proposing their 1858-theories of descent with modification via natural selection [3, 5, 13].

Evolutionary Biology and the Future of the Biosphere

In the light of the SyNaDe-model in its expanded version, we have to conclude that there is no longer a single, unifying "Darwinian evolutionary theory". Since ca. 1990, the synthetic theory of the 1940s developed into modern evolutionary biology. This branch of the natural sciences consists of a number of theories that describe and explain different aspects of the diversification (and extinction) of all forms of life on our ever changing (dynamic) "planet of the microbes".

Today – in an era called the *Anthropocene* – the biosphere of "Mother Earth" is dominated by one cooperative/aggressive, cosmopolitan "Us- vs.-Them"- Primate species (*H. sapiens*) [16]. These "self-domesticated, hair-less apes" (member of the Hominidae) determine the fate of all the animal- and plant-life that has remained intact since 1858, when Darwin and Wallace published their principle of transformation of species via natural selection [3, 5, 13]. It is sad to recognize that our daughter species, the chimpanzees, are severely endangered by reckless, egocentric humans, many of whom may regard *Homo sapiens* as the "Crown of Creation", equipped with the "natural" right to drive other macro-organisms, such as apes, to extinction.

Glossary: Key terms and definitions

Common descent: Fact that all organisms on Earth are genealogically related, and descended from a ca. 3800 million year old Last Universal Common Ancestor (LUCA). The origin of LUCA via chemical evolution has not yet been elucidated.

Darwinian fitness: Relative lifetime reproductive success of an individual within a variable population, or number of surviving offspring, compared to conspecifics.

Darwin-Wallace-Principle. Fact that all organisms produce more offspring than the environment can support; the resulting "struggle for life (or existence)"–i.e., the competition for limited resources, leads to natural selection – the elimination of the unfit and the survival of the better adapted individuals.

Evolution: Descent with modification, i.e., the cumulative change in the characteristics of populations that occurs in the course of successive generations under ever-changing environmental conditions, resulting in new species and body plans.

Natural selection: Process that determines the composition of a population during the course of time; under changing environmental conditions, directional selection causes adaptive evolution and hence the occurrence of new variants and species, as implicated by the Darwin-Wallace-principle.

Population: Unit of evolution, i.e., a group of variable interbreeding organisms that lives at the same time in a specific environment (habitat).

Sex: Bi-parental reproduction via the meiotic creation and subsequent mechanical fusion of two different haploid gametes, usually egg and sperm, resulting in a diploid zygote that can develop into offspring. Meiotic Sex occurs in almost all eukaryotes. It "creates" variability and mutations (often causing heritable diseases; "meiosis-sex-dilemma").

Species: Reproductively isolated group of organisms, breeding among themselves that have the greatest mutual resemblance, and may consists of one or numerous populations.

Symbiogenesis: Primary endosymbiotic events that gave rise to organelle-bearing (mitochondria, plastids) eukaryotic cells and Sex during the Proterozoic, and subsequent secondary endosymbioses responsible for the origin of unicellular marine phytoplankton.

SyNaDE-model: Theory that posits that Symbiogenesis-Sex, Natural selection, and the Dynamic Earth (Plate tectonics, volcanism, plus major climate changes) are the key processes that have caused macro-evolutionary changes in populations of organisms over millions of years of Earth's history.

Acknowledgements

This project was supported by grants from the Alexander von Humboldt-Stiftung, Bonn, Germany (AvH-fellowships Stanford / San Francisco, CA, USA, to U. K.), and by Dr. Rajnish Khanna, I-Cultiver, Inc. Manteca, CA 95336, USA (CEO of I-Cultiver/California). https://orcid.org/0000-0001-8095-2180.

References

[1] Kutschera U. Evolution. Ref Mod Life Sci., Elsevier 2017 Art. 06399: 1–5.
[2] Kutschera U. Symbiogenesis and cell evolution: An Anti-Darwinian Research Agenda? In Delisle, R.G. (ed.). The Darwinian Tradition in Context: 309 –331; Springer International Publishing AG 2017.
[3] Kutschera U. Charles Darwin's *Origin of Species*, directional selection, and the evolutionary sciences today. Naturwissenschaften 96; 2009: 1247–1263.
[4] Kutschera U. Fom the scala naturae to the symbiogenetic and dynamic tree of life. Biology Direct 6/33; 2011:1–20.
[5] Kutschera U. Evolutionsbiologie. Vom Ursprung der Sexualität zum modernen Menschen. 5. Auflage. Verlag Eugen Ulmer, Stuttgart 2025.
[6] Dobzhansky T, Ayala F, Stebbins G L, Valentine J W. Evolution. W. H. Freeman & Co., San Francisco 1977.
[7] Kutschera U, Ehnes I. Darwin's toxic tropical land planarians invade California and Europe: New records. IJISET 11/5; 2024:1–5.
[8] Kutschera, U., Niklas, K. J. The modern theory of biological evolution: an expanded synthesis. Naturwissenschaften 91; 2004: 255–276.
[9] Hinch R, Donnely P, Hinch AG. Meiotic DNA breaks drive multifaceted mutagenesis in the human germ line. Science 2023; 382:1012.
[10] Hörandl E, Speijer D. How oxygen gave rise to eukaryotic sex. Proc R Soc B 285/20172706; 2018 :1–9.
[11] Mayr E. What Evolution Is. Basic Books, New York 2001.
[12] Niklas K J. Plant Evolution: An Introduction to the History of Life. The University of Chicago Press, Chicago 2016.
[13] Futuyma, D. J., Kirkpatrick, M. Evolution. Fifth Edition. Oxford University Press, Oxford 2022.
[14] Kutschera U, Niklas KJ. Evolution of sexuality in animals and plants: From Julius Sachs 1874 to HMG-box genes. Biol Theory 2025; 20:1–11.
[15] Root-Bernstein M. Evolution is not driven by and toward increasing information and complexity. Proc Natl Acad Sci USA 2024; 34/e2318689121: 1.
[16] Glowacki L. Robust evidence that mobile hunter-gatherers participated in war: Comment on Fry (2025). Evolution Human Behav 2025; 46/106658: 1–11.