Chapter 30
On How Epistemology and Ontology Converge Through Evolution: The Applied Evolutionary Epistemological Approach

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Outline

Philosophy traditionally distinguishes epistemology (the map) from ontology (the territory). Epistemologies provide knowledge on the ontological state of certain aspects of the world. Cosmologies are epistemological frameworks that concentrate on the nature of matter, space, and time. Traditionally, matter, space, and time are made intelligible through hierarchy theories that describe the ontological layeredness of the cosmos; and causality theories that render mechanical explanations for this layeredness (sections 1-2). In classic cosmologies, the map and the territory are considered different from one another. Ancient scholars maintain realist positions on how their maps reference the world but such a first philosophy is currently refuted (3). Socio-anthropological schools question any linkage between the map and the territory, and understand epistemology as an outcome of sociocultural practices, while traditional evolutionary epistemological schools maintain hypothetical realist positions. By adhering to adaptationist and Neodarwinian views on evolution, organisms are considered hypothetical theories on the outer world (4). Here, we go further by demonstrating that organisms are not just theories about the world but spatiotemporally real entities (5). Organisms evolve knowledge and reproduce it into their offspring, and through processes such as symbiosis and niche construction, they acquire and extend knowledge onto other organisms and onto their niches (6). Life builds realities and it enables for a realist position where the evolving map equals the evolving territory. We revise traditional evolutionary epistemology accordingly (7). The conclusion is that truth and reality are spa-

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tiotemporally bounded and prone to change in congruence with the organisms that build it and the niches they construct (8).

The Map (Epistemology) and the Territory (Ontology)

Philosophy is traditionally divided into two subdisciplines, *ontology* or the study of existence (that what is), and *epistemology* or the study of knowledge (how we humans come to know that what is) (Ferrier 1854: 44–46). Following the metaphors of this anthology, epistemology provides a *map,* or a *theoretical* or *methodological* means to conceptualize or draw the map of the *territory,* which traditionally refers to the cosmos and all the entities it contains. The entities that exist and the processes that unfold between them are the *object of knowledge*. They are what is being mapped or investigated epistemologically (Fig. 30.1).

Epistemological frameworks on the cosmos underlie the formation of *cosmologies* which are philosophical, religious, ideological or scientific *worldviews* on the nature of *matter*, *space* and *time* (Gontier 2011, 2016b). Cosmologies are illustrated in *cosmographies* which are descriptive and sometimes explanatory *diagrams* or maps that visualize how (aspects of) matter, space and time arrange in the cosmos. Classic examples include Ancient Middle and Far Eastern Wheels of Time or Chains of Being or Medieval Scales of Nature (Barsanti 1992; Lovejoy 1936; Gontier 2011) (Fig. 30.2).

Modern cosmographies include scientific diagrams of entities existing on a *micro-scale* (atomic particles, chemical elements, RNA and DNA molecules, or amino acids); *meso-scale* (trees, webs and networks of life, Fig. 30.3); and *macro-scale* (diagrams of the solar system or the universe).

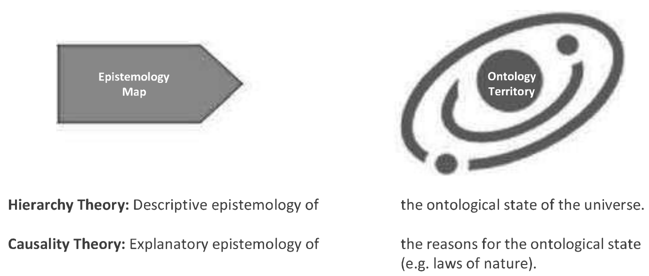


Fig. 30.1 Schematic of the classic ontology/epistemology divide

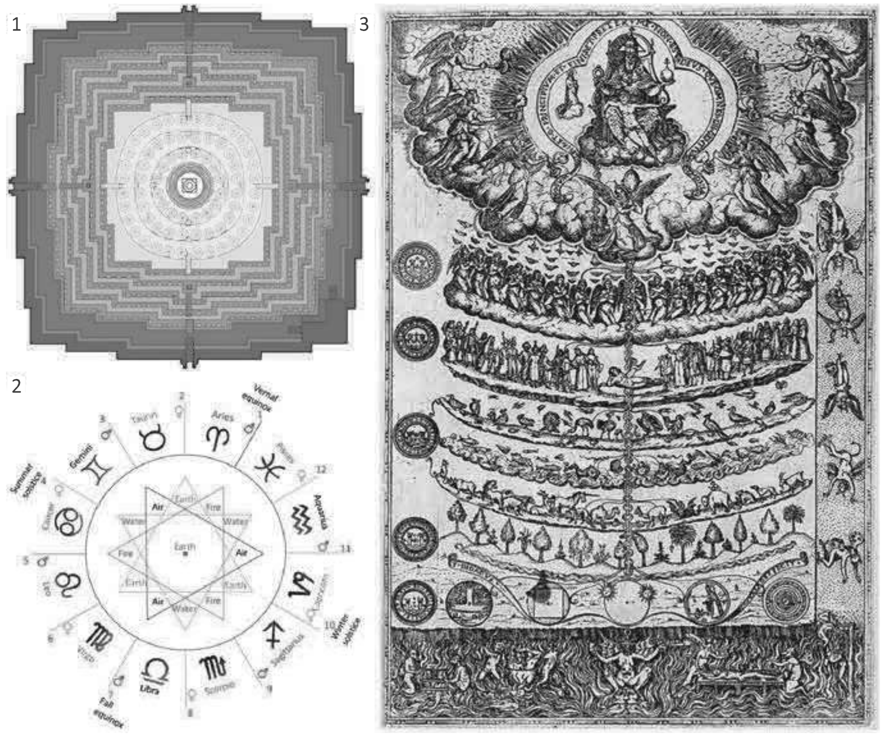
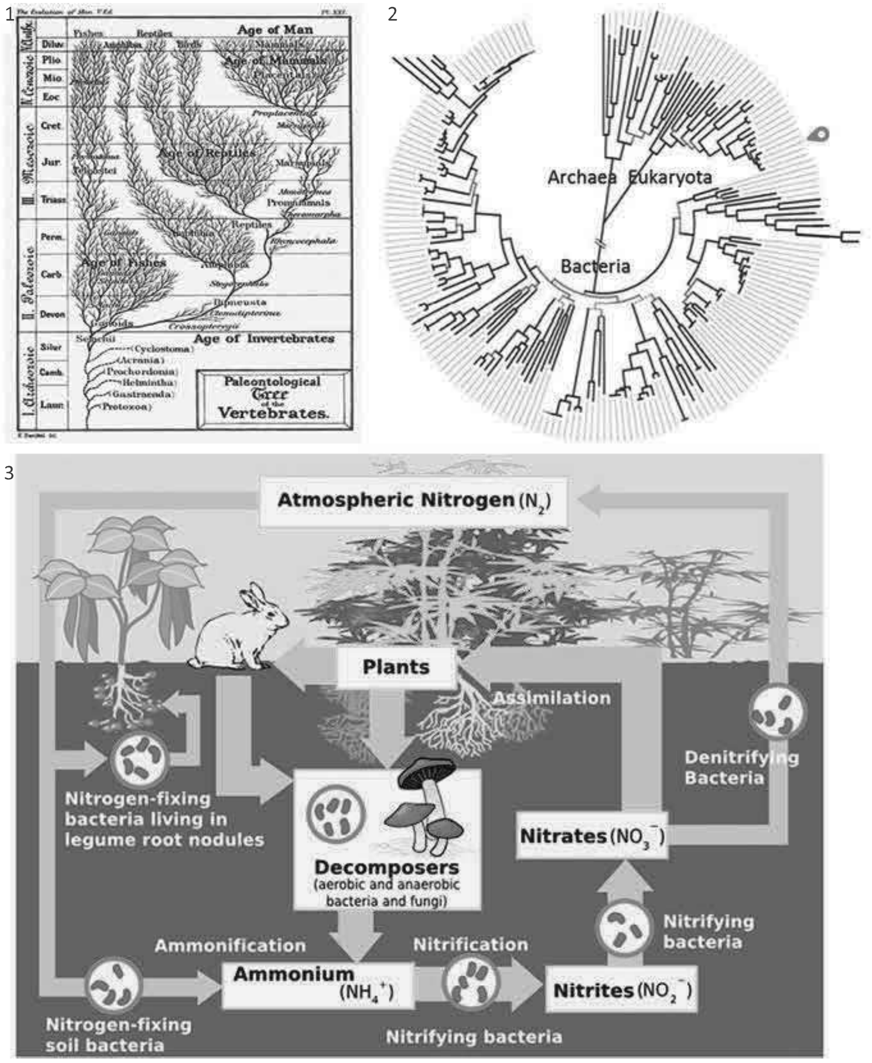


Fig. 30.2 Cosmographies of ancient Far Eastern (1) Middle Eastern (2) and Judeo-Christian cosmologies (3) that demonstrate the hierarchical nature and the underlying causes of the cosmos. (1) Representation of the floor plan of the Buddhist Borobudur temple, located in Indonesia, in the form of a *mandala* or wheel of time. The yellow inner circles represent the realm of formlessness (chaos), the orange middle layers represent the realm of form (the permanent), and the red outer layers represent the realm of desire (the temporal world). (2) The tropical zodiac. It represents a chain of being (the constellations are presumed to be chained animals or gods); a wheel of time (because the zodiac provides a calendar of the Platonic great year and a 360-day year); and a causal explanation for the rotation of the star signs around a geocentric earth (based upon the four elements). (3) A Judeo-Christian reinterpretation of Aristotle's chain of being that was based upon his three-soul theory and determined by the returning cycle of coming (generation) and becoming (decay). For Christians, the chain forms a single and unilinear ladder or stairway to heaven, going from the least to the most perfect beings. The level of perfection is "measured" by the distance that exists between beings and the deity that resides in heaven. The strands of the ladder go from plants over land, water and air animals, to humans and saints. The Christian deity stands above creation and outside of matter, space and time, and is surrounded by angels. Underneath the ladder, we find the underworld that is ruled over by the devil. On the right, we see some falling angels on their way to hell (Credits: (1) Image by David1010, made available on Wikipedia, https://upload.wikimedia.org/wikipedia/commons/8/8b/Borobudur_Mandala_ka.svg; (2) own work; (3) Image by Diego Valadés for *Retorica Christiana* (1579: 218), digitalized by the Getty Research Institute and available under creative commons at https://archive.org/details/rhetoricachristi00vala)



Hierarchy and Causality Theory

Cosmologies and cosmographies associate with *ontological hierarchy theories* that *describe* how matter can be *classified* in space and over time and with *metaphysical* or *ontological causality theories* that explain the *reasons* for this hierarchical order (Gontier 2015b, 2016b).

Fig. 30.3 Scientific diagrams that represent aspects of the living world. (1) Haeckel's (1874) paleontological tree of vertebrates, set in quadrant I of the Cartesian coordinate system (the left columns represent the y-axis marking time, the right column represent the x-axis delineating space). The image provides a chronology of when fishes, reptiles and mammals first originate in the geological time scale. Haeckel's diagram depicts common descent of vertebrates from invertebrates, extinction (the end of lineages), and speciation (the ramification of lineages that mark the rise of new species). These processes are explained by natural selection theory. (Credits: The image comes from the 1879 English translation of the work, and is made available under a creative commons license at https://en.wikipedia.org/wiki/Timeline_of_human_evolution#/media/File:Age-of-Man-wiki.jpg). (2) Adoption of Bork & co-workers' tree of life (Ciccarelli et al. 2006). This unrooted (unhistorical) tree depicts the evolutionary distance between 191 extant species whose whole genomes have been sequenced. The distance is measured by comparing genetic divergence of 31 genes held in common by all these species, and that are involved in the translation of the genetic code. The diagram represents the *most likely* phylogenetic relationship that exists between the species. The tree demonstrates that eukaryotes (multicellular life forms) are more closely related to Archaea than to Bacteria. Archaea and Bacteria are both prokaryotes (unicellular organisms), but they are genetically distinct from one another making some scholars doubt they share a single common ancestor. The red dot on the right marks the location of our species (*Homo sapiens*) on the tree. When making their diagrams, neither Haeckel nor Bork and colleagues took horizontal gene transfer, hybridization, or symbiosis into account, which are processes that can also cause genetic divergence or convergence between species. (3) A cyclic network diagram that demonstrates the important role bacteria, fungi, animals and plants play in the earth's nitrogen cycle. The processes are explained by ecology and symbiosis theory that detail how distinct organisms interact amongst themselves and with the abiotic environment. (Credits: Image by Johann Dréo and made available on Wikipedia under a creative commons license at https://en.wikipedia.org/wiki/Nitrogen_cycle#/media/File:Nitrogen_Cycle.svg.)

Hierarchy Theories

Hierarchy theories provide *descriptions* of the ontological state of the universe (Fig. 30.1). The classic Greek hierarchy, for example, divides the cosmos into an embedded micro-, meso-, and macrocosmos. Other examples, that also root our current division of the sciences, include Hutton and Spencer's distinction between the inorganic (physico-chemical), organic (biological) and superorganic (the sociocultural, ecological and universal); or Julian Huxley's division of the world into a physical, biological and psychosocial level (Gontier 2015b). The fact that different ontological hierarchy theories exist demonstrates that any claim made on ontology remains an epistemological endeavor.

Different cosmologies often apply *different classificatory principles* to build the ontological hierarchy and the criteria used are a means to separate, compare and understand different cosmologies. Far and Middle Eastern cosmologies (Fig. 30.2 (1)) classify the world into *realms* and differentiate between chaos (that what has no form), the permanent (what has a lasting from), and the temporary (what has a form that will generate and decay). Ancient Greeks continue these ideas and their classifications rest on the conjectured *soul* entities have. Inanimate matter has no soul, plants have a vegetative one, animals a sensitive (mobile) one, and humans have a rational soul (Barnes 1984). Judeo-Christian scholars continue Greek classification and build scales of nature that hinge on the presumed level of *perfection* entities have, which is "measured" by how close or distant they are from their deity (Fig. 30.2(2)). 19th century natural history scholars classify entities chronologically, based upon their first appearance in (calendrical) time and space (geographical and geological location). From these chronologies they derive notions of (ontological levels or *amounts* of) *progress* and *complexity*, which are used as additional criteria to classify and understand the order in the world (Fig. 30.3(1)).

Today, biologists classify species by their *level* of *evolutionary relatedness* which is measured by the *amount* of *genetic distance* that exists between organisms. One level down the hierarchy, chemists continue to classify matter based upon the elements that make them up; and another level down, quantum physicists investigate the subatomic level where time and space as we know it dissolve. Biologists and physicists also continue to use *complexity* criteria, as well as additional criteria of *optimality*, *likelihood* and *parsimony* (economy). These are quantitative measurements that enable an examination of how "probable" their cosmologies and cosmographies on the ontological state of the universe are (Fig. 30.3(3)). Note that measuring in terms of optimality, likelihood and parsimony involves a switch from "certain," "real," and "true" to *uncertainty* on how the map links to the territory.

Causality Theories

While hierarchy theories attempt to provide *descriptions* of the ontological state of the universe, causal theories attempt to provide *explanations* for it (Fig. 30.1). *Metaphysics* is a term used synonymously with ontology. It was introduced by Latin scholars to refer to a series of texts written by Aristotle that became classified after his work on Physics (Barnes 1984). Because these works discuss the presumed reasons for the underlying order of the physical world, what Aristotle called a "first philosophy," *meta*-physics can also be understood as the study of that what underlies, brings forth, or enables the physical hierarchy. This pertains to matters of *causality*.

Ontologically, Aristotle distinguishes material from formal, efficient and final causes and he assumes the existence of a primary cause to the cosmos which he calls the unmoved mover (Barnes 1984). It steers the souls in their returning cycles of coming and becoming. The unmoved mover has no cause and undergoes no change but is ultimately responsible for all movement that occurs within the cosmos. This includes the returning cycles of coming and becoming over time, and all motion of matter in space. Judeo-Christian cosmologies take over his metaphysical worldview, and reason that the unmoved mover and the cosmos it sets in motion are created by a deity. Any movement in the world occurs according to divine will.

For natural history scholars, the world abides by constant (unmoving or unperturbed) physical and biological forces, laws or mechanisms that uniformly determine the past, present and future in straight-line causal trajectories (understood in Newtonian physics and set in a Cartesian coordinate system). Laws are constant irrespective of the phenomena to which they apply.

Today, the sciences question the notion of uniformity and instead think in terms of contingency and non-linear dynamics that they model in vector and Hilbert spaces (Eldredge 1985; Gould 1989; Prigogine 1980; Smolin 1997). Classic hierarchies that depict a linear order of entities in space and over time are making room for network diagrams that demonstrate how entities *interact* and generate processes in an “extended present” (Gontier 2016b).

Modern sciences redefine causality. Non-linear dynamics and contingencies make scholars question whether constant forces, laws and mechanisms are independent entities that have existence in the world “out there”. Instead, they favor *contextual process accounts* of nature. An apple will fall from a tree, unless you happen to break that fall by catching it. An explanation of the apple’s fall thus needs to take the surroundings into account.

Natural selection is traditionally understood as conditional upon the existence of genetic and organismal variation, heredity, and environmental selection (Darwin 1859). These are all *processes* or *phenomena* that occur in the world (Whitehead 1929; Campbell 1974; Hull 1988; Gontier 2017). If these processes do not occur in tandem, then natural selection does not exist; and if this cycle does not repeat over long periods of time, then evolution by means of natural selection does not occur.

Cultural evolutionary theories have demonstrated that many more processes are selective. Cultural evolution (Campbell 1974; Mesoudi 2016; Bradie 2017) occurs through variation in ideas, beliefs, rituals or material artifacts that are the subject of differential learning and teaching, resulting in the retention of some of that variation in cultural tradition over others. Though the phenomena studied by biologists and anthropologists differ, the processes whereby the living and the sociocultural realms change are both selective, and both lead to a pattern of descent with modification. Selection subsequently does not manifest a law that exclusively occurs within the biological domain. Instead, many different processes that involve different entities and phenomena are selective. This implies that phenomena and processes, and not abstract laws, determine the nature of selection.

Summarizing, the goal of epistemology is to acquire knowledge on the ontological state or order of the cosmos by finding its hierarchical structure and the causes that generate this hierarchy. Such knowledge is quintessential because it enables us to understand the world and navigate within it, but we remain bounded by epistemology.

No First Philosophy

Historical research demonstrates that scholars have visualized and conceptualized the territory by different maps. Different epistemologies make us realize that *a map is not identical to the territory*. Stated otherwise, there is no one-to-one correspondence between the map and the territory. Rather, any map provides a *view* or *window* to the territory, or the map merely highlights specific aspects thereof. Why there is no straightforward one-to-one correspondence between the map and the territory subsequently becomes an independent research question.

The traditional ontology/epistemology distinction was made before the recognition that we live in an evolving world that forms part of an expanding universe and possibly a multiverse. Ontologically, it assumes:

(1) the existence of matter, space and time;
(2) the existence of one singular, hierarchically embedded cosmos; and
(3) the existence of causality, i.e. reasons that are formulated by causes, laws or mechanisms, for why the cosmos is what it is.

Epistemologically, it assumes that humans can gain absolute and true knowledge on the hierarchical and metaphysical or underlying causes of the cosmos.

These ideas track back to the ancients and the early natural history scholars that work from within a *paradigm* we now call *realism*. It is one of the oldest theoretical schools of thought developed by human beings, and one that makes the most "common sense".

However, numerous scholars have now demonstrated that many of the assumptions traditional realists made are *biased* toward and *informed* by how we, as historical, biological, cognitive, social and cultural beings, perceive the world. These ideas go back to scholars such as Hume, Kant, Herder, Husserl, Freud, Durkheim, Boas and Kroeber. How we perceive or conceptualize the world *phenomenologically* does not always, if ever, correspond with how the cosmos really is (James 1909).

We perceive ourselves as individual beings, though our bodies house three times as many micro-organisms than human cells. We perceive matter but not the (sub)-atomic particles that make them up, nor the processes that exist amongst matter and energy (Whitehead 1929). We experience our material existence as organized in time and space or place while modern sciences have demonstrated that the mass of matter and energy are interchangeable, and the independent existence of space and time is questioned and substituted by the notion of spacetime.

It makes us realize that our senses, our thinking and our languages by which we formulate cosmologies are often biased. They are biased toward our *Zeitgeist* and *Heimat*, what we today designate as our social and cultural upbringing or folk psychology (Stich 1983). And they are biased toward our evolved biological constitution (Lorenz 1941; Campbell 1974; Popper 1963) and the constraints it imposes upon our cognitive-perceptual apparatus (Goldman 2006; Bechtel 1988).

This makes us conclude that:

(1) unfalsifiable knowledge on the territory is hard to come by (Popper 1972); and
(2) the ontological state of the world, the traditional subject of ontology, is often defined differentially depending upon the epistemological paradigm (Kuhn 1962), the research program (Lakatos 1978), or the language (Quine 1951) one works in.

The *first problem* acknowledges that we can no longer assume a straightforward one-to-one correspondence between our knowledge of reality and how reality is. This makes us face an additional problem. Namely, how we can measure and compare how and to what extent our knowledge does corresponds to reality. It requires an investigation into the *content* of epistemologies, how "true," "valid," "confirmable," "testable," "(un)falsifiable," "likely," "parsimonious," and "optimal" our epistemic theories and methodologies are when they make ontological claims. Answers continue to be sought by philosophers (of science), but they are nowadays also sought by scientists.

The *second problem* asks about the origin, history and nature of epistemology beyond the content of theories and methodologies whereby it approaches ontological problems. This requires an investigation of epistemology from within the historical, sociocultural, cognitive and biological sciences.

It is important to note that in both accounts epistemology is investigated from within the sciences.

Studying and testing the content of scientific knowledge or the sociocultural and cognitive-biological act of doing epistemology from within the sciences involves a rejection of a first philosophy and an acknowledgement that there is no "God's eye view" to the world or a divine language whereby we can express matters of fact. Instead, we recognize that our languages evolved naturally, and that the knowledge we acquired is fallible, contemporary and prone to change in association with the progress made within the sciences.

The Origin, History and Nature of Epistemology

Turning to the second problem, we can roughly distinguish between two different schools of thought: the socio-anthropological school of knowledge, and the evolutionary epistemological school of knowledge. Their names foretell how they understand the study of knowledge.

The Socio-Anthropological School of Knowledge

This school goes back to scholars such as Wittgenstein and Foucault, and recognizes:

(1) that we cannot prove that our epistemological languages, diagrams, theories or methodologies refer to the word;
(2) that "regimes of truth" are partially biased, if not fully determined by human social, political, economic and cultural factors; and

(3) that the act of science or a more broader form of knowledge-seeking is a sociocultural *activity* influenced by "language games" that need to be studied as such.

Socio-anthropologists subsequently understand knowledge, not as a relation between individual human knowers and the world, but as *a relation between different human knowers* (Munz 1993). Knowledge is neither the imprint of the world upon our senses as empiricists used to think, nor an object of the mind as rationalists proposed. Knowledge is *capital* or the property of sociocultural and linguistic groups (Fig. 30.7). How and if knowledge relates to the external world (often interpreted as a physical one) becomes secondary, with most scholars in this school originally concluding that it is impossible to transcend our sociocultural and linguistic roots whereby we investigate the world. Rather, humans live in a super-organic (Sapir 1917) or super-physical world distinct from the physical and biological realm, and that superorganic structure functions as one "superorganism" (Spencer 1876).

Historically, this stance traces back to 18th century romantic movements that culminate in 19th century nationalist schools for the homeland, home culture and home language, against all others. Some of its worst outcomes include solipsism, xenophobia, racism, ethnocentrism and ethnic cleansing associated with the two world wars.

Knowing the terrors early natural history thinking had led to, and in opposition to the latter views, socio-anthropological schools from the 1950s onward opposed the nationalist schools. Going back to scholars such as Herder, Boas, Kroeber, and Whorf, socio-anthropological schools put forward historical particular, relativistic, post-modern, post-structural, post-colonial and overall deconstructionist schools of thought that often make claims against science.

It is important to emphasize that these schools fight against science as it was defined in modern times, during the Enlightenment. This references a period in time determined by Newtonian and Cartesian mechanics in physics, and unilinealism or orthogenesis adhered to in early sociology, anthropology or biology. These schools all assumed that matter in motion, biological organisms, or the history of humans, their knowledge, their languages and their cultures, follow inescapable "straight-line trajectories" or "developmental laws" toward "progress" and "increasing complexity". These claims were presuppositions protruded by anthropocentric and Eurocentric ideas that have now been proven unwarranted and plainly false. To differentiate these unjustified theories from scientifically-grounded forms of natural history research on the natural origins of organisms, societies, cultures, languages and sciences, the older views have been renamed *historicism* (Popper 1957) and *evolutionism* (Sahlins 1970).

Questioning one epistemological framework however does not need to result in a rejection or complete abandonment of science, which is what some sociologists and anthropologists of science ended up doing. Questioning the scientific endeavor altogether brings forth the following two issues:

(1) It does not accord with the progress science makes (Laudan 1977); and
(2) It underestimates its very own claim about the power human beings have in developing epistemological frameworks as well as languages, societies and cultures.

Regarding the *first issue*, a mere comparison of older with current paradigms demonstrates that humans have gone well beyond the knowledge acquired by the ancients. Knowledge not only increases, especially the medical sciences demonstrate that certain, although most certainly not all problems can be solved. And we have been able to develop new ways by which we study organisms, languages, cultures and human history, which prove that the older ideas are indeed biased and false. This does mark progress because we can make use of science to rule out false theories. Rejecting this latter claim would place early racial claims on par with current genetic evidence that proves that on average, all humans differ only 0,02% from one another. This demonstrates that we all belong to the same species and thus that humans cannot be differentiated into distinct races. Though both claims are theories, and both are *incommensurable* because different methods and paradigms are applied (Kuhn 1962), current knowledge proves that the older ideas are false and the current correct.

Regarding the *second issue*, the social turn toward epistemology developed as a claim against a first philosophy and against science. But it has failed to see the knowledge they themselves have provided about the social and cultural act of what it means to do epistemology. For they have brought forth an epistemology of their own, one that demonstrates how epistemology indeed results from linguistic, sociocultural, and historical group endeavors. This can not only be studied, it can be studied from within the current historical, linguistic, sociocultural and anthropological sciences. Data can be quantified, new methodologies have developed, and theories can be construed.

The Evolutionary Epistemological Schools of Knowledge

Evolutionary epistemologists agree with most socio-anthropological claims on human knowledge, and go further by asking *how knowledge evolved in all biological organisms, and how they as groups construct their environments*. Evolutionary epistemology no longer understands knowledge as confined to cognition or language and as unique to humans. Rather, it examines:

(1) how all organisms acquire knowledge (or perform the act of epistemology);
(2) what the content of organismal knowledge is;
(3) how, over the course of evolution, they reproductively and socio-culturally produce, acquire, transmit and extend that knowledge into their progeny, onto other organisms, and into their environments.

The evolutionary epistemological school of knowledge goes back to scholars including Hume, Descartes, Kant, and Quine. They reasoned that the expectations we have about the world, the mathematical systems whereby we calculate the world, the languages we use to refer to the world, and the causal relationships we humans tend to abstract from our observations, can be better made sense of from within the field of psychology or what we now call the neuro-cognitive sciences.

In line with the rise and diversification of the evolutionary biological sciences, evolutionary epistemologists today ascertain that evolution is the *precondition* for all cognitive, communicative, and sociocultural knowledge that biological individuals and groups acquire, produce or transmit and extend into their environments (Bradie 1986; Gontier 2006; Wuketits 2006).

Different Evolutionary Theories Engender Different Epistemologies

Evolutionary sciences are diverse and there exist different evolutionary schools. In this part we detail how adherence to one school over another also brings diversity into the evolutionary epistemologies proposed.

Different Evolutionary Schools

The *Modern Synthesis* adheres to a Neodarwinian framework and examines how environmental selection acting upon genotypes and phenotypes brings forth new species. Organisms passively undergo selection that unidirectionally comes from an active, selecting environment.

Developmental biologists examine eukaryotic organismal development from conception until death. Extending the phenotype (Dawkins 1989), they *internalize* selection (Levin and Lewontin 1985; Gould 1977) and demonstrate, on the one hand, that organismal development occurs through a complex network of interactions occurring within the body and between gene-regulatory systems, organs, neurons, vascular, lymphoid and hormonal systems (Griffiths and Gray 1994); and on the other, the physico-chemical, biotic and sociocultural environments. This results in multilevel selection theory (Lewontin 1970; Okasha 2005) as well as evolutionary developmental and epigenetic schools that examine how the environment can alter the organism and its future generations and vice versa (Wolpert 2009; Jablonka and Lamb 2006; Hallgrimson and Hall 2011). It calls for a dualist (Craver and Bechtel 2007; Bechtel 2011) and dialectic view (Levins and Lewontin 1985) on how genes, organisms and environments relate to and interact with one another; and it brings forth the notion of *epi-genetic inheritance*, which refers to changes in gene expressions and protein functions induced by the environment.

Paleontologists investigate the evolutionary history of species as it presents itself in the fossil record which is calculated in a geological time scale, and macroevolutionary scholars study above species phenomena and investigate the causal impact the abiotic world has on life, through, for example, meteor impacts or climate change (Eldredge 1985).

Ecologists such as Van Valen (1973) demonstrate that in so far as selection occurs in the outer environment, that environment is by and large made up of other organisms. This raises questions on within and between group competition and selection (Maynard Smith 1964; Wynne-Edwards 1986), as well as how groups or colonies of the same species often behave as superorganisms (Wilson 2005), that sometimes have extended minds. Much of the latter is calculated by cost-benefit equations as they developed within kin selection and rational choice theory.

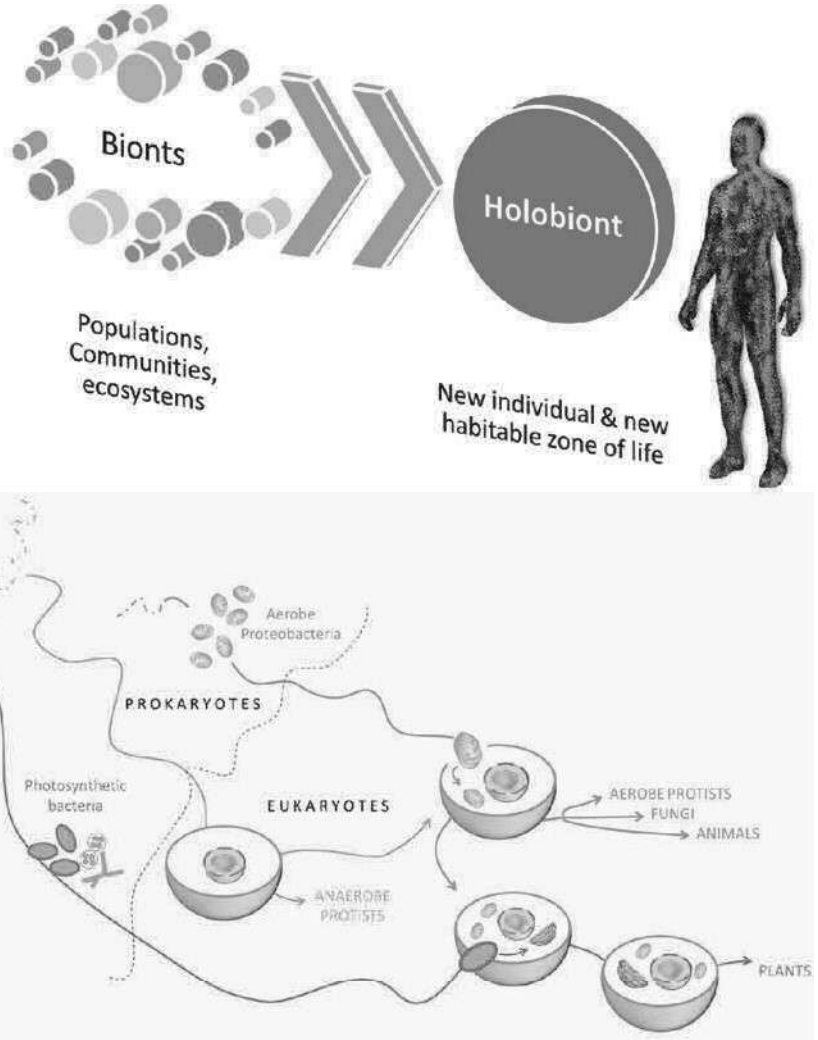
Symbiologists (Margulis 1991; Margulis and Sagan 2000) investigate how biological individuals often interact mutualistically with organisms only distinctly related to them and how they form ecological associations that have an impact that reaches well beyond the biotic environment. Life, for example, is responsible for over 90% of the oxygen present in the earth's atmosphere, and life can induce climate change. Interactions between organisms are called symbiosis and the interacting organisms are called symbionts. Symbiotic associations can underlie the formation of new tissues, organs, traits, or even new individuals called holobionts (Fig. 30.4).

Holobionts are new biological individuals comprised of different organisms (bionts) that simultaneously function as new habitable zones of life for those bionts. A human being, for example, is not a single organism but an entire ecological community consisting of bacteria, viruses, and sometimes fungi that live in- and onside its body. Our bodies provide a new habitable zone of life for our microbiome, and our microbiome mutualistically returns the favor by underlying vital functions such as digestion.

Independently living unicellular organisms and symbionts of eukaryotes often exchange genes amongst themselves and with the host through processes of *horizontal gene transfer* (Zhaxybayeva and Doolittle 2011). Such transfer is called horizontal because it occurs during ontogeny and no (vertical) reproduction is required to acquire the genes. When horizontally acquired genes enter the nucleus, they can be passed on vertically via host reproduction.

Several organisms also directly pass on their symbionts to their progeny. *Wolbachia*, for example, are parasitic microbes that live inside several insect species. In fruit flies, the microbes can penetrate the female eggs, leading to maternal transmission of the *Wolbachia* species. *Wolbachia* can impact the reproductive success and survival of its fruit fly hosts (Faria and Sucena 2015).

When symbiosis becomes hereditary, it is called *symbiogenesis* (Fig. 30.4). When symbiogenesis or lateral gene transfer occurs, it results in *evolution through reticulation* that is characterized by lineage crossing or blending of lineages leading to a web or network instead of a tree of life. Other forms of reticulate evolution include hybridization which also enables expansion into new ecological territories,



thereby enabling hybrids to extend their habitable zones of life (Anderson 1949), and it enables rejuvenation of the genome.

Finally, Rousseau's observation that humans build their sociocultural environments has been extended toward other biological organisms under the label *niche construction*. Niche construction theory was first introduced within the field of ecology by Lewontin (Gould and Lewontin 1979; Levins and Lewontin 1985; Lewontin 2000). Beyond humans, all organisms often interact with the environment in ways that are specific to the organism, and all organisms actively participate in construing their and other organisms' niches. Niche construction calls out for the recognition that inheritance extends the germline, it can be ecological. And

◀**Fig. 30.4** Symbiosis and symbiogenesis. Symbiosis is an ecological phenomenon that refers to the fact that many different species live in close association with one another, either inside or onside of one another, and permanently or temporary. Symbiosis underlies the formation of holobionts that function as new biological individuals (top image). Symbiotic relations can take on many forms, ranging from mutual and beneficial to detrimental for one or all. Many of these symbiotic relations, such as the acquisition of our microbiome, are necessary for good health but only occur during and after birth. Nonetheless, symbiosis can become hereditary and lead to symbiogenesis which is evolution through symbiosis. Symbiogenesis delineates the process whereby new tissues, organs or species evolve by permanently incorporating members of older species. Symbiogenesis has played an important role in the formation of the nucleated cell and the origin of the four eukaryotic kingdoms that include the protists, fungi, animals and plants (bottom image). Aerobe proteobacteria penetrated early eukaryotic cells and evolved into mitochondria that are present in most protist, all fungi and animal kingdoms. Some early eukaryotes in addition incorporated cyanobacteria that evolved into chloroplasts present in all plant cells and chloroplasts were acquired multiple times over through secondary and tertiary symbiotic events. In all cases, the bacteria lost their identity and individuality and became part of the body of the holobiont, as cellular organelles. Nonetheless, their ancestors still roam earth today, as individuals

ecological inheritance (Odling-Smee 1988) typifies both biological and sociocultural evolution (Laland et al. 1995).

Summarizing, there exist different views on what evolution is, how it occurs, and who does the evolving. Many of the above theories originally developed outside the Modern Synthesis which is the standard paradigm that explains how evolution occurs by means of natural selection. New mechanisms and processes have been introduced, and attempts are made to extend the Modern Synthesis in order to include schools such as Eco-Evo-Devo that combine insights from ecology, development and evolution (Pigliucci 2009). The various processes whereby life exchanges information horizontally and reticulately are being grouped into new reticulate evolutionary paradigms that emphasize the important role symbiosis, symbiogenesis, hybridization and infectious heredity play in evolution (Gontier 2015a). Most of all, and causally, it calls out for a pluralistic stance: evolution occurs by a variety of distinct mechanisms and processes that often occur simultaneously. Your gene expressions might be altered by your environment and you might be incorporating new genes through lateral gene transfer acquired from one of your symbionts.

Varied Evolutionary Epistemologies

Evolutionary epistemologies are equally diverse and depend upon the evolutionary views adhered to. In fact, evolutionary epistemologies evolve with them. Many of the founders of evolutionary epistemology (Lorenz 1941; Campbell 1974; Skinner 1986) actively participated in founding (comparative) behavioral, ethological, cognitive and sociobiological evolutionary sciences.

The research programs have now been incorporated into these sciences that study how cognition, behavior and communication evolves in all biological species, how organisms embody that cognition, and how it relates to the organism's external environment. For classic evolutionary epistemologists, the question how evolved organisms relate to an outer, physical world remains meaningful. Traditional fields study organismal traits exclusively from within Neodarwinian schools of thought that emphasize adaptationist views. Adaptation is a term first introduced by Lamarck and "literally (refers to) the process of fitting an object to a pre-existing demand …" by assuming that "organisms adapt to their environment because the external world has acquired its properties independently of the organism" (Lewontin 2000: 43). Supporting that selection occurs from the environment onto organisms, traditional evolutionary epistemologists understand organisms as unfalsified *conjectures* or *theories* about the world that somewhat corroborate to it (Campbell 1974; Popper 1963). This enables and endorsement of *hypothetical realist* views. Epistemology understood as evolved knowledge continues to be different from ontology or the world as it is in itself, and the question becomes how the evolved theories or hypotheses that come in the form of organisms refer to the outer world.

Today, due to advances in eco-eco-devo, evolutionary epistemologists endorse radical constructivist (Riegler 2006) and non-adaptationist views (Wuketits 2006), as well as moderate (instead of hypothetical) realist views on how knowledge relates to the outer world (Clark and Chalmers 1998; Munz 1993; Ruse 1989). In moderate realist views, the mind and organismal bodies function as media or mediators between organisms and the environment. In radical constructivist views, the mind has priority in constructing an experiential world of its own that does not necessarily relate to an outer world. And from within non-adaptationist views, knowledge is understood as a *relation between organisms* in the same sense as socio-anthropologists and socially-oriented philosophers of science understand it as a relation between human knowers. How this knowledge relates to an outer, physical world then becomes secondary.

In the remainder of this work, we shall extend upon these traditions and go further than moderate realist, constructivist and non-adaptationist views by demonstrating that the relation between epistemology (in the form of organisms) and ontology (as an "outer world") becomes superfluous. Organisms reconstruct the earth, not just in their minds, they *embody* that knowledge in their anatomy and cognition, and they *extend* it onto their progeny and into the niches they construct. Ever since life evolved, life has rebuilt earth inside out, recycling existing matter, energy and space made in previous moments in time, into a living earth, up to the point that earth no longer exists as a purely physical "outside" entity. If that abiotic entity once existed, it now exists no more. Rather, it evolved into a living planet through the organisms that reconstruct it from its subatomic particles onward by reproducing and constructing new material life forms as well as extended and equally material niches.

Organisms and the environments they build (epistemology understood as evolved knowledge) are what is real (ontologically), and the relation is *exclusive* because there is no outer abiotic earth anymore. Our living planet is not just hypothetically real, it is spatiotemporally real, or stated otherwise variant in time and space.

Organisms build biologically-informed or evolved realities or bio-realities that include the construction of local environmental and sociocultural niches. The living earth evolves in congruence with these expanding (generating or speciating) and contracting (degenerating or perishing) bio-realities that are dependent upon organismal and species survival, reproduction and extinction as well as the ecological materializations they bring forth in time and space (or spacetime). Epistemology, *understood not as theories but as the evolution of embodied knowledge in organisms and their extended niches that underlie bio-reality formation*, therefore *equals* ontology, the current living world. One might call this position *radical spatiotemporal realism*, but I prefer to understand it as the outcome or consequence of *applying evolutionary frameworks* to matters of *epistemology* that show that epistemology equals ontology, which I call *applied evolutionary epistemology*.

A New Cosmology

We started this chapter by demonstrating how cosmologies render epistemologies on the cosmos by providing theories on the nature of *matter*, *space* and *time*. Thus far this has involved a consideration of how matter occupies space which results in *hierarchy theories*, and how matter extends over time which results in *causality theories*. But the cosmologies developed so far are static and do not take evolution of either the map or the territory into account.

Today, we know that *matter* is equivalent to *energy*, space and time are joined into a four-or-more dimensional *spacetime*, and there is growing support that our cosmos forms part of a *multiverse*. How we have conceptualized matter, space and time is therefore not (completely) true.

Matter and energy, we find in the organisms that constantly recycle and rebuild a new earth out of an older one, through the acts of consumption, reproduction and expulsion. Living organisms constantly generate new matter and energy that they extend into their progeny, onto other organisms and onto the environments they rebuild and construct anew. As such life regenerates or *re-cycles* earth (its old *spaces* it occupied in the past), and we build a new earth (or new spaces in time, or new *space times*).

Advances made in modern physics as well as socio-anthropological and evolutionary epistemological schools demonstrate that we have outlived the classic epistemology/ontology divide. It is no longer useful to us, because there is no single static cosmos “out there” that organisms acquire knowledge on or adapt to. What is real evolves which makes reality variant in space and time. What is true at one point is therefore not necessarily true at another, which makes knowledge spatiotemporal or local. In so far as organisms embody and extend their knowledge into their progeny and onto their environment, they make reality happen every day. We make the living earth happen every day. However local and variant reality and knowledge might be, they are both real, and what is more, they are equivalent. In this part, we demonstrate how *epistemologies simply are ontologies*, which makes any distinction between them unsustainable.

Thinking Through the Consequences of Symbiosis and Niche Construction for Ontological Hierarchy Theories and Causality Theories

Niche construction and symbiology theories make a straightforward link between epistemology and ontology, or the organisms and the niches they construct on the one hand, and the outer physical world on the other, problematic. Here we think through the consequences of symbiosis and niche construction for the construction of bio-realities.

But before we do, we need a note on niche construction. Niche construction theory was redefined by Odling-Smee (1988) and Laland et al. (1995) as a form of adaptability or a capacity to become adapted to the outer environment. This view is now incorporated into the new evolutionary sciences that include evolutionary psychology, evolutionary linguistics, evolutionary anthropology, evolutionary sociology and evolutionary archeology. This move is rather unfortunate. Lewontin (2000), who coined the term, defined niche construction as a capacity for organisms to develop a world of their own, distinct from what exists "out there," or better yet, what existed before constructing organisms entered the scene. It enables survival *despite* the environment organisms are born into.

Contrary to this view, current niche construction theories emphasize adaptation or adaptability of organisms to existing sociocultural or biotic niches that are local in scope. It underestimates the very claim made about the important role generations of organisms have in actively building a world of their own, and it recalls the problem also socio-anthropological schools face. They too underestimate the creative force of humans in actively construing their sociocultural and linguistic environments and in lieu focus on deconstructing science. A consequence is that they understand organisms to primarily conform or adapt to a given and somewhat stable biological or sociocultural environment, which are the niches constructed, and only in a later phase can individuals modify it. It underestimates the creative power organisms have in continuously bringing forth new niches, new bionts and new holobionts.

However, an organism-based construction results in new realities that are different from the older ones and that surpass the older in both space and time. They do not infiltrate existing structures or fit on top of older structures, they *replace* older structures. Niche construction theory can fare much better by abandoning both its notions of adaptation and adaptability. These are non-evolutionary because they accept an outer, somewhat stable world. Adaptation or superorganic realms are concepts belonging to older cosmologies, they are not part of the new worldview that is developing. For the same reason, we shall also surpass Levins and Lewontin's (1985) Hegelian and Marxist dialectic position.

Turning to reticulate evolution, it conflicts the traditional views on the genealogical (gene or replicator-based) and ecological (phenotype or interactor-based) *hierarchy* (Tëmkin and Eldredge 2015). The genealogical and chronologically linear hierarchy traditionally goes from genes to cells, organisms, species and higher taxa. However, reticulate evolution crisscrosses and jumps between levels of such a hierarchy, often instantly creating new genealogical hierarchies that take on the form of holobionts at any level of an existing hierarchy. A holobiont is often made up of bionts belonging to the three different domains of life; hybridization can occur between distinct sub-species and species belonging to different genera, families or orders; and lateral gene transfer occurs within and between prokaryotes and eukaryotes. Reticulate evolution instantly alters existing genealogical hierarchies creating new ones that have their own trajectories. And it alters spatiotemporal ecological hierarchies that traditionally line up as going from organisms to populations, communities, ecosystems and the biosphere. One holobiont is an entire ecological space or habitable zone of life for the bionts that make it up.

So far scholars have only studied life in space and over time, but not in spacetime. Linear and single hierarchies induce discussions on arrows in time (Gould 1989; Prigogine 1980), on how major transitions between levels of a linear hierarchy occur (Maynard Smith and Szathmáry 1995), and on how *causality* occurs; upward, which brings forth reductionist worldviews (Dawkins 1983), downward (Campbell 1974), which brings forth holistic views, or through a combination of both (Bechtel 2011; Lewontin 2000) which brings forth cyclic or dialectic views (Fig. 30.5).

Upward causation correlates with linear hierarchies that describe and explain events over *time* (in chronologies, for example, or *genealogies*). The focal level is the level of study, and in upward causation, the focal level is explained by going down one level of the hierarchy. Suppose the focal level is the organism. To explain how it originates in time, Neodarwinians go down one level of the hierarchy to genes and examine how they form organisms (e.g. Dawkins 1983). Organisms in turn bring forth species. This gives a straight-line and irreversible trajectory, and when investigating the history of life, it makes sense that species cannot precede organisms that build them, and organisms cannot precede genes that underlie organismal form.

In *downward causation*, the focal level is explained by the level above the focal level. It associates with holistic views, and it investigates matter in *space* or what we may call an *extended present*. Examples include *ecological hierarchies*. Suppose the focal level is again an organism. To explain group selection, which remains a controversial theory, scholars go one or two levels up the hierarchy to populations and communities and examine how they can cause (groups of) individuals to be decimated, to go extinct, or, to be favored in the inter-organismal struggle for existence. This can only happen when (different) groups, populations,

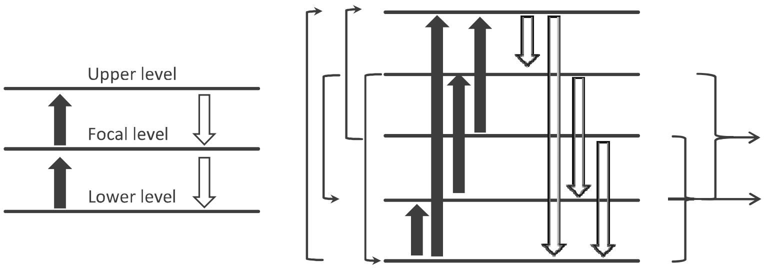


Fig. 30.5 Traditional versus new hierarchical views on ontology and causation. *Left*, the traditional way whereby scholars understand hierarchies as either undergoing upward causation (marked in the black arrows) or downward causation (marked by the white arrows). *Right*, we depict how we are going beyond classic notions of causality. So far, focal levels are only explained by the levels close to them, one level up, one level down, or through a combination of both. For one, there is no reason that either up- or downward causation cannot extend their influences on more than one level up or down the hierarchy (depicted by the same arrows as in the figure on the left), or by simply skipping some levels in its causal influence (depicted by the black arrows on the left of the levels). Secondly, and what is typical about symbiosis and other types of reticulate evolution, is that it jumps in between levels of the chronological or genealogical hierarchies, instantly creating new ones (depicted on the right by the accolades). The picture shows that it cannot be depicted comprehensively in traditional hierarchical lineups, which is why scholars are turning to network diagrams

and communities already exist, which requires a study in space or in an extended present. Similarly, suppose the focal organism represents a human child learning to write his language. It learns it from its teachers that are part of his community, and the child can only learn how to write his language because the community already has a writing system.

Great controversy resides over whether downward causation is not just upward causation recurring cyclically or recursively over time (e.g. Craver and Bechtel 2007; Bechtel 2011). It depends upon how one understands the phenomena tracked and represented by the focal level, either as identical and resulting from the same trajectory (stable genes that are faithfully transmitted over generations of, nonetheless different individuals), or as resulting from a different trajectory (because each individual is unique and thus has its own trajectory), or from a trajectory that perhaps crosses the focal level (through, for example, lateral gene transfer). The latter two examples imply *non-linear* and *multi-linear* dynamics and interactions *between different hierarchies* which requires *non-linear and multi-linear causation theories*. A sometimes causes B, B is sometimes caused by a combination of C or E, and at other times by D.

Although not stated explicitly, this view is adhered to by Eldredge (1985; Tëmkin and Eldredge 2015), who understands the genealogical and ecological hierarchy as different from one another yet interacting.

One of the things that symbioses demonstrates is that we need to go beyond. There is a reason why these events are being depicted by networks instead of hierarchies. Bacteria can instantly infect organisms at any “scale” or “level” of the hierarchy, and when they do, they bring forth a new reality in the form of a holobiont that immediately also functions as a new habitable zone for life. They *pop up* at any existing level of the hierarchy, and *jump* between hierarchies, without having to rewind or relive the previous genealogical chronology or grouping into an existing ecology. When trying to model that in traditional hierarchies (Fig. 30.5 **on the right**), it does not look clear, while networks or webs of life facilitate comprehension.

By investigating how the genealogical and the ecological hierarchy interact, Tëmkin and Eldredge (2015) open new research questions on how many hierarchies there are, and how they can become combined (Gontier 2010, 2017). In short, it necessitates pluralistic accounts on hierarchies that are better depicted into networks set in vector or Hilbert spaces, keeping in mind, of course, that networks remain hierarchical, and that any event has its own peculiar trajectory. And they require new causal explanations.

Much of these networks nowadays remain "unrooted" because we have no idea how to conceptualize *time* which today often is no more than a measure of distance in space. But we can go further than that. What processes of reticulate evolution and niche construction demonstrate, is how entities and processes, *distinct in space and time* from one another, are combined into a new *spacetime*.

Perhaps what I am saying can be made sense of by drawing analogies with Einstein-Rosenberg bridges that alternatively go by the name of "wormholes". But caution is required. For one, a wormhole, as traditionally conceptualized, is still too small (10^{-33} cm or -230000000 nm) for even the tiniest virus (i.e. the *Porcine circovirus*, 17 nm or 0.000002 cm) or prokaryote (i.e. the *Nanoarchaeum equitans* archaea, 400 nm or 0.00004 cm) to pass. Nonetheless, scholars are calculating how wormholes can be stretched. It is remarkable though, that it is viruses, archaea and bacteria, the smallest living entities on earth, that are so swift in their crisscross travels across niches and organisms in space and time or spacetime. Physicists theorize about parallel universes or the impact spacetime travel has on the traveler. On earth, one can safely say that symbiosis changes the identity of the traveler. Free-living cyanobacteria are quite different from the chloroplasts they evolved into when they entered eukaryotic cells; and every chloroplast inside a plant cell, is just like the nucleus of that cell, unique because of its specific genetic code as well as its life history. Viruses, such as the flu, attack in specific periods in time and space which leads to epidemics and pandemics. But where they go to in between, nobody really knows. If they are always around us, and everywhere, they should infect us all the time too. But some do not, and it is more likely to catch them in specific times of the year, around infected individuals. Viruses contain the most different genes, about 80% of them are exclusively found in these viruses. Several scholars (Villarreal and Witzany 2010) also consider viruses as preceding and perhaps underlying the origin of life on earth. If they would be space time travelers, then, and if you allow me the anthropomorphic expression, their attempts at infecting us makes one wonder what kind of (passed, distant or distant past) world they are trying to salvage by bringing it into the present hoping it will survive.

Another issue with wormholes is that they have this almost mystic air around them. But there is no reason to assume they only occur in galaxies far away. Theoretically, they can also take place right next to you, and perhaps even inside of you. Physicists do not know what happens once something goes inside, or what happens once it comes out, if that is at all possible. Biologists on the other hand, can not only observe bacterial or viral infections with their microscopes in “regular space”, genetic engineering actually induces them all the time. Through acts of artificial symbiosis and artificial lateral gene transfer, genetic engineers alter genetic codes of organisms. By inserting foreign genes into viruses and letting them infect laboratory animals they investigate what anatomical, cognitive and behavioral changes the new genes induce. Whether this just happens in space and time or in spacetime and through wormholes is really something for physicists to calculate and have their say about. For now, it’s a good metaphor by which we can think about these phenomena and investigate them further.

Because we can readily implement these ideas in our daily lives. Search your house for all the electronic equipment you have, and check the date and location it was manufactured. You have been bringing quite some different matter, made in different spaces or places with different time zones and manufactured in past years together during your lifetime. Yet it all forms part of your extended present. We are accustomed to understanding our houses as the result of labor and transportation of goods due to commerce and consumption, but perhaps that view is old-school and it is, instead, a form of spatiotemporal travel enabling you to create your niche. Your smartphone might be the same brand as mine, produced in the same year and the same factory, but it is different from mine because of its content. The same goes for the bionts we gather during our holobiont lifespans, and all can be captured by the notion of universal symbiosis (Gontier 2007).

Turning to *how we conceptualize the past*, we are accustomed to thinking about the past as something that lies behind us, in what is called a distant past. In our cosmographies, it resides somewhere far away on the lowest scale of the ladders, timelines or hierarchies we have built. But one of the things current physics is teaching us is that the past is, in fact (not just in poetry) all around us. We see the moon as it was 1.2 seconds ago, and the sun as it was 8 minutes ago. The more distant in space we look, the more back in time we go. The Hubble telescope, for example, enables comparisons of other galaxy formations it observes in space which enables conclusions on how our galaxy possibly formed (https://www.nasa.gov/press/2013/november/hubble-reveals-first-pictures-of-milky-ways-formative-years/#.WfStRWiPI2w).

In the opposite direction, gravitational waves or ripples in spacetime are teaching us is that some of that past is just reaching us now. Two years ago, observers detected a gravitational wave in spacetime that was presumably caused due to the collision of two black holes, far away from us and in a distant past (Abbott et al. 2016). When the gravitational wave passed by, it was rather swift at that, and wherever it is headed to, it concerns its own future, which might not necessarily be ours. Ever since, scholars have detected other such waves to pass by.

Coming to Terms with an Expanding and Evolving Multiverse

Symbiology demonstrates how *multiple* holobionts are formed from bionts that in turn construct new niches that additionally function as new and multiple ecologies. Holobionts, as niche constructors and as ecology providers, extend and significantly alter the world.

The "outer" world or environment where epistemology tries to get a grasp on has classically been interpreted as singular and purely physical. It either corresponds to the universe, earth, an abiotic environment, or a "more fundamental" physicalist level. (Holo)bionts alter that physical world and play an important role in "abiotic" processes such as the nitrogen, oxygen or carbon cycle, the earth's temperature, and the earth's atmosphere (Volk 2017). On earth, most organisms turn into dust, mud, soil or stone because if the conditions are not right, they will not be preserved. But no matter how deep one goes into water or digs inside the earth's mantle, so far life is found everywhere. Even in volcanos and acidic environments. Life thus significantly alter the spheres of the earth, extending well into space.

Dissecting any (holo)biont to its smallest particles, we find that they are made up of the same (sub)atomic particles that build matter. But those particles simply do not *explain* all there is to life. A reductionism to a purely physical stance is unwarranted. And downward or cyclic causation does not suffice either because life builds new genealogical and ecological hierarchies all the time, thereby introducing new spaces that all follow their own times and that combine different times or circadian rhythms together. Since its origin, life has incessantly created new realities from the subatomic particles onward and it is all real. It has created numerous new phenomena displaying all sorts of behavior.

Living organisms evolve this knowledge and transmit information on it to future generations, on to organismal neighbors, and they store it outside of them in their extended niches. This knowledge does not so much provide a theory about an outer physical environment, as information on how bio-realities can become construed and how one can survive within them.

Bio-realities alter the purely physical realm inside out, up to the point that such a realm has no independent existence anymore. That means that if earth once was a purely physical or physico-chemical object, today that object exists no more. It has traded place with the incessantly and newly evolving bio-realities. Life simply replaces the physical earth by recycling it.

On that view, knowledge no longer concerns a hypothetical relation between an organism and its external environment. *Knowledge is an evolving phenomenon that materializes into organisms and the overlapping biological realities they construe* (Fig. 30.6).

There are no doubts about adaptation, correspondence or truth values of the knowledge and information that life evolved, because there simply is no independent physicalist or physical ontological reality to compare it with. What is true for one organism, might not be true for another, but it does not make any of these organisms

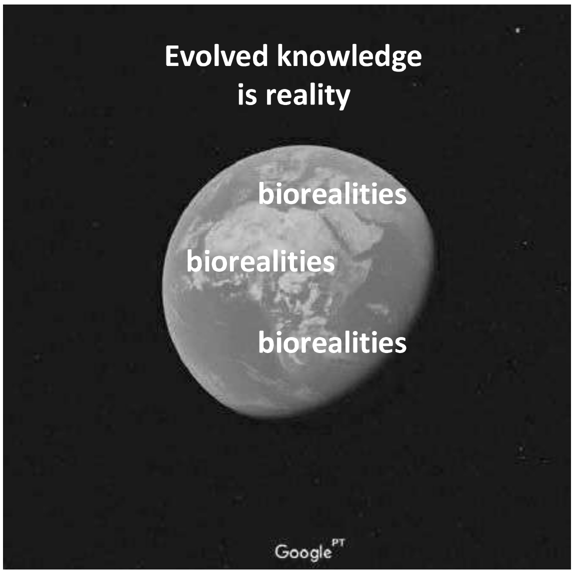


Fig. 30.6 Bio-realities and the equivalence between evolved epistemology and evolved ontology (Photo obtained from Google Earth that is under a creative commons, and adapted)

less real or existent. And what is true in one niche might not be true in another, but that does not make it less real locally. They *are* the currently existing *realities*.

Ontologically, the only comparison we can make is how the living earth relates to other planets and how it stands in the universe or multiverse. But on the one hand, that implies such a redefinition of ontology that one can wonder how useful that is. It would make more sense to give up on the ontology/epistemology distinction altogether.

On the other hand, we did not make the oceans of our world, but we use them for transport and we pollute them which alters their biotic and abiotic composition. We and other organisms such as the wolves that were reintroduced in Yellowstone Park change river banks and all organisms, even bacteria, change the composition of the soil and the atmosphere. We do not make the planets orbit around the sun, but we witness the events. There is a *past* universe out there. And in our entangled ways, we are the ones that see the material traces or the light it left, by bringing it into the present and into our biological realities through our evolved cognition and the extended instruments we make such as the Hubble telescope.

Some scholars wonder, for example, if the black hole that presumably resulted from the collision of two black holes, and that presumably caused the gravitational wave, is still there now, in its present. But one of the things our current knowledge on the speed of light and our measurement in light-years teaches us is that we are looking at structures belonging to a distant past. What the Hubble telescope sends back might be a picture of the "dead," comparable to tangible fossils we find in geological strata of species long extinct.

Our trips to the moon or one day soon mars furthermore demonstrate that we can bring the past into the present. And in so doing, our trips or technological missions such as the Mars Rover change those entities. If they were once lifeless (which is currently questionable for Mars), they are now planets where earthly life has extended toward. That is what evolutionary scholars call variation or even speciation through time, or what philosophers call a change in kinds. Life changes the ontological state of (parts of) the universe, not merely by thinking it with our minds, but by observing it happen or by actually doing it by going there and altering what once was, forever.

Finally, there is no real reason not to understand the physical cosmos or multiverse as a living "something", just like Lovelock and Margulis (1974) understood earth as a living planet. The cosmos can be understood as an individual that has a beginning, lifespan, and end (Ghiselin 1974). We already know that the universe metabolizes by expanding, and it is likely to reproduce by making more selves (Smolin 1997; Everett 1957). If true, then the multiverse, just like us organisms, evolves knowledge and constructs its own worlds. It makes symbiosis not only universal (Gontier 2007), but multiversal (but see Volk 2017, for example, on an abiotic view).

Summarizing, there simply does not exist one eternal physical or physicalist world out there, and there does not exist one truth. The universe or multiverse might be more durable in time, but it is not fixed. It also changes and evolves. What we are left with here on earth, are expanding and contracting biologically-informed realities or bio-realities.

For a detailed research program on how evolving knowledge and transmission thereof can be studied in all organisms from within these diverse evolutionary sciences, we refer the reader to Gontier and Bradie (2018; Gontier 2010, 2012). Here, we continue to focus on the implications of how we understand epistemology defined as evolved and extended knowledge and information.

Revising Traditional Evolutionary Epistemologies Considering the Newly Evolving Cosmology: Implications for Knowledge and Truth

Classic evolutionary epistemological insights include that:

(1) Organisms are embodied theories about the environment (Popper 1963; Campbell 1974; Wuketits 2006);
(2) Mechanisms are methodologies or heuristic search engines for acquiring theories about the environment (Campbell 1974; Riedl 1980);
(3) Human theories are disembodied organisms that evolve (Popper 1963, 1984).

We can adjust these views and say:

(1) (Holo)bionts are not just embodied theories, they are real and so is the knowledge they embody and evolve; and we can add that the niches they provide for other bionts, and the niches they build are not extended theories but spatiotemporal realities or bio-realities that often extend their makers in spacetime;

(2) mechanisms need to be replaced by process accounts, and what we find is that distinct processes have converging patterns in modes and tempos;
(3) the content of knowledge and the constructs (holo)bionts make indeed evolve, in congruence with their evolution; consequently, truth or reality is not one but varied; but in each variation, knowledge and reality (or the map and the territory) are equivalent.

(Holo)Bionts Are and Construct Bio-Realities

One of the major claims made by classic evolutionary epistemology is that it understands organisms as embodied *theories* (or conjectures in the Popperian sense of the word) about the world. Knowledge subsequently becomes redefined as a relation between the organism and its environment. Here, we examine and compare this claim to how socio-anthropological scholars define the historical, cognitive and sociocultural nature of epistemology and how philosophers of science evaluate the content of epistemology (knowledge). Afterwards, we examine how knowledge materializes in progeny, in other organisms, and in niches, making claims about an independent environment unwarranted.

Epistemologies as Methodologies and Theories, the Socio-Anthropological View

Epistemologies provide *knowledge* of the territory (understood as an independent or outer physicalist, biological or sociocultural world) through *theories* and *methodologies* (Fig. 30.7).

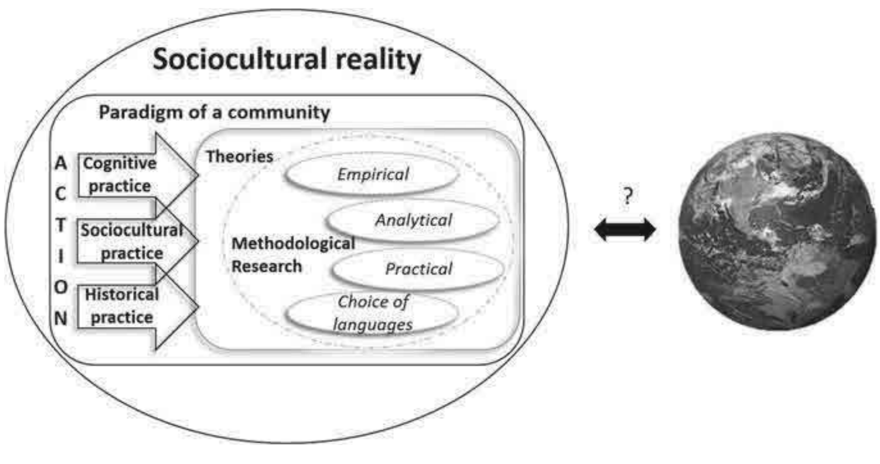


Fig. 30.7 Socio-anthropological view on epistemology. The figure also portrays what is known as the *reference problem*, the question of how human knowledge that is formulated in natural, formal, or mathematical languages relates to the world

Theories are obtained by *empirical* (observational), *analytical* (ideational, conceptual) and *practical* (experimental, instrumental, and technological) research that abides by *methodologies or* research *programs*. Research programs delineate a set of procedures or rules for how research is performed and how theories are formulated. Boundaries between theories and methodologies are indeed fuzzy, with some positing the primacy of methodologies over theories (Lakatos 1978), while others claim the opposite (Popper 1963; Kuhn 1962). Fact is that many of the current methodologies that scientists apply are informed by theories and vice versa.

One way to distinguish between them is by understanding methodologies as corresponding with *the act of doing epistemology which is acquiring knowledge* (through e.g. science). Theories refer more narrowly to the specific results obtained, i.e. *the content of epistemology which is knowledge*.

Theories are traditionally articulated in natural, formal, or mathematical *languages*, and applying methodologies often involves a choice of particular languages over others to formulate theories (Russel 1914; Stewart 2011).

Both theories and methodologies are dependent upon, and informed by human *cognition* as well as *historical and socioculturally-informed individual and group action* or *power* and *practice* (Bourdieu 1977) that is defined through concepts including field, habitus, capital, and doxa. Human *cognition* results from embodied, embedded, enacted, and extended minds (McLuhan 1964; Clark and Chalmers 1998; Rowlands 2010); and *action* results from *historically-informed, individual and sociocultural group behavior*. Together they form *mentifacts* that underlie *sociofacts* that often materialize into cultural *artifacts* that include scientific instruments (Huxley 1955). The result is knowledge that *extends* the individual knower, the sociocultural group it belongs to, and the time and place it first originated. Materialized, knowledge gives way to what Rousseau called artificial cultural societies, societies that extend and surpass our biological nature and natural habitats. This view grounds the classic nature/nurture divide, and the idea of a super-organic structure that is superimposed upon the biological and physical realm. Methodologies, the theories they propagate, and the cognitive, historical and sociocultural practices that underlie them are referred to as epistemological frameworks or paradigms (Kuhn 1962). Paradigms refer to the totality of knowledge of a scientific community. Summarizing, epistemology always has three sides to it:

(1) a methodological part that is itself informed by theory that refers to the act of doing epistemology which refers to acquiring knowledge;
(2) a content part, that refers to the actual knowledge that becomes formulated into theories;
(3) performing methodologies and formulating theories are cognitive, linguistic and sociocultural, individual and group endeavors that extend and materialize into sociocultural territories or realities.

(Holo)Bionts and the Niches They Build Are Knowledge

Here, we demonstrate that (holo)bionts meet all requirements imposed on *methodologies* that enable *an act of doing epistemology* which leads to the *acquisition of knowledge*.

All (holo)bionts *empirically* explore their extended present, mostly for food or shelter, and in most eukaryotes, for mates. They observe their niches. If not by making use of their evolved bodies that sometimes enable locomotion or complex senses than enable vision, touch or smell, then through complex biochemical processes. Slime molds (Reid et al. 2012), for example, are colonies of individual slime cells. These cells can live independently, but they often team up. They do not have a nervous system and thus nothing that resembles a memory. Nonetheless, when foraging for food, they will avoid places where they have foraged before. Not because they "remember" where they have been, but because they avoid the biochemical signals their slime trail left in the places they already foraged. The trails they leave function as an external memory map that enables successful navigation and exploration of their local niche. All (holo)bionts possess knowledge about their local niche, and they externalize it and leave trails of it, which is part of the process we call niche construction. Many (holo)bionts also perform *analytic research* of their niche. Animals do not always need to act to know or learn something. A moth flies to the light and burns its wings and dies. But we rarely see horses or lions walk into a fire or jump off a cliff. The neurocognitive sciences have demonstrated that thinking can be non-linguistic, and what we are used to call categories of the mind is present in other animals. Most eukaryotes "know" or recognize their children, and they know how many there are because they will look for them when lost. Spatiotemporal awareness, number sense, paternal and maternal relationships are traits currently studied and found to have evolved in quite a number of species. Many primates in addition have rudimentary theory of mind. They know that others know. Consequently, they will hide food or suppress food calls from others and only share with conspecifics of which they know shared food with them, or helped with grooming or fights.

All (holo)bionts evolve *practical methodologies*. Socio-anthropological schools of thought define practical methodologies as experimental, instrumental and technological research. Behavioral research has demonstrated that we are not the only ones that do so. Many species engage is social play which is often a way to experiment or practice hunting and fighting. Numerous (holo)bionts make use of their niche to build instruments or tools. A honeycomb is an extended complex instrument and technological complex that houses larvae and fabricates and stores honey. Termite mounds are equally complex factories that function as protecting nests for their inhabitants. Ant and bee colonies function as single individuals or superorganisms (Wilson 2005), and such requires complex forms of communication between e.g. the workers, the soldiers and the reproductives.

Turning to language, that might be uniquely human. But many (holo)bionts have evolved *complex communicative systems* for intra- and interspecies communication as well as for internal e.g. intracellular communication. Much of this can be studied from within the field of biosemiotics (Witzany 2014). Ants communicate through pheromones. RNA intermediates between DNA and proteins. Bacteria communicate through chemotaxis. Viruses possess the biochemical keys of our bodies locks, and they can fence of or immobilize our body's immune responses. Prey have often evolved forms of mimicry and either have the shape of predators, or they take on the colors of the niche to hide from them. As Darwin already noted, sentient organisms have evolved a series of expressions and emotions that inform their niche about their physical or mental state. Mice communicate through ultrasonic vocalizations, bats through echolocations, snakes understand their niches through heatmaps, and scorpions and butterflies not only see but respond to ultraviolet light. Primates have evolved complex multimodal forms of communication that make use of a combination of vocalizations, gestures, expressions and emotions, and, in humans, we add to that words or symbols. Words are by far the most deceptive way whereby we can communicate false or fantastic ideas that *dissociate* with the niche. Most animal communication systems are instead *associative*, they communicate about real-life events though they can lie about whether they are ongoing or not. In sum, (holo)bionts and the structures they are composed of have evolved methodologies that enable them to *acquire* and *build* knowledge that they *transmit* and *extend* onto their offspring and into their surroundings where it *materializes* and *alters reality*. In so doing, (holo)bionts and their extended niches are more than just theories about an external world. *They are knowledge, and that knowledge exists in the living earth that is made by it, they are reality.* Knowledge therefore is reality, or, stated otherwise, the map evolves the territory.

Evolved Knowledge Materializes into New Realities, Epistemology Understood as Knowledge Equals Ontology

In association with the evolutionary sciences, evolutionary epistemologists demonstrate that all (holo)bionts possess and evolve knowledge about their internal and external niches. In association with the socio-anthropological schools of thought, they have demonstrated that all (holo)bionts are actors in this world. They have evolved anatomical, cognitive, behavioral and sociocultural practices that extend into and modify existing niches and (holo)bionts pass on this knowledge, through the germline, horizontally and multi-directionally through learning.

We can add that this underlies the formation of new, biologically-informed or evolved realities which we call bio-realities (Gontier and Bradie 2018). Bio-realities are neither "purely" physico-chemical, nor exclusively biological or sociocultural. They are also not a new "realm" that "emerges," "infiltrates" or seats on top of older realms. They are new realities in spacetime that *replace* older realities, all the way down to its subatomic levels. They are, what ancients used to call a microcosmos that embeds within it a macrocosmos. And our living earth in turn is embedded within a multiverse.

Although this work focusses on bionts and holobionts, the evolved genetic codes can also be understood as evolved methodologies that provide information on material biont formation. Besides being in constant communication with our cells and our extended present, they are by far the most erudite on how the abiotic matter that surrounds us can, from the subatomic level onward, be recycled and brought into our world as living matter and energy. And the life it brings forth in turn incessantly alters the genetic codes through, for example, introgression of foreign genes into existing genomes.

In sum, the distinction between theory and knowledge becomes superfluous. (Holo)bionts and their niches are real entities in the world that underlie the formation of altered or new realities. Knowledge can no longer be understood as a homogenous entity that refers to a homogenous outer world of which some of its levels are more real, stable or permanent in time than others. Knowledge is particular and dependent upon the evolved bio-realities. What is true in one niche is not necessarily true in another, and when (holo)bionts die, their knowledge often dies with them, unless they were able to transport it into the niche, offspring or other (holo)bionts. Nonetheless, a purely solipsist view is impossible, because we are evolutionary related by common descent, and we all inhabit the living earth.

Process Accounts and Recurring Patterns

Traditional evolutionary epistemologists mainly worked from within Neodarwinian schools and understood evolution to happen by means of natural selection that was interpreted as a mechanism. Many also understood natural selection as a *methodology* that acquires knowledge about the world (Campbell 1974; Riedl 1980). On that account, natural selection is nature's way to build *theories* about an outer world.

Today, scholars recognize that evolution can occur by a myriad of "mechanisms" including drift, symbiosis, lateral gene transfer that all refer to distinct and ongoing processes. These theories are currently being "universalized" towards domains that extend the classic biological sciences, such as linguistics, sociology, and anthropology. As explained in the introduction, many social and cultural processes can be understood as selective. Interesting in that regard is that especially Campbell, and though not explicitly, understood "universal selection" as a recurring *cycle* of what he called *blind variation and selective retention* occurring over repeated periods of time. This cycle brings forth a pattern that recurs in the evolution of culture, of languages, and of anatomical form. "Descent with modification", is another pattern selection brings forth, but all known "mechanisms" bring forth this pattern.

Reticulate evolution, that brings forth horizontal patterns of information exchange and lineage crossings or blending, also characterizes processes of language mixing, or cultural hybridization. Drift theory that brings forth random patterns of evolution not only typifies how genes or (holo)bionts migrate and evolve, it is also found in how languages and material artifacts diffuse. And besides gradual patterns, also the pattern of punctuated equilibria (Eldredge 1985) has been found in the evolution of certain languages, species, and material cultural artifacts (Gontier 2015b).

A universalization of evolutionary mechanisms often implies a transition from mechanism to process accounts as well as an identification of recurring patterns (Gontier 2017, 2018). Process accounts demonstrate that mechanisms are not laws or forces, but conditional upon phenomena behaving in particular ways. It is the phenomena that demonstrate selective behavior or not, but there is nothing above or beyond the phenomena. Selection is not some force or law out there waiting to act. Only phenomena and processes exist. Mechanisms do not exist and can therefore not be methodological. Recurring patterns, these continue to provide *heuristic* information on how evolution occurs (Campbell 1974). But finding pattern similarities requires an observer that selects or directs attention to some but not other data. Though they provide knowledge on evolved processes, patterns do not provide methodologies for life to evolve. At best, they provide methodologies for a scientific observer.

In sum, the distinction between organisms as methodologies or theories becomes superfluous. Organisms are methodologies that underlie theory or knowledge formation, and to explain the evolution of real organisms, we can only refer to processes that in turn refer to real phenomena. Real phenomena often have pattern similarity, although that might result from our observing eye that chooses to focus on some but not other data.

Human Knowledge, Like All Knowledge, Evolves

Finally, by expanding epistemology to all domains of life, classic evolutionary epistemologists have demonstrated that knowledge evolves. It evolves in the form of embodied theories (which are identical to real (holo)bionts) and in the form of disembodied (holo)bionts (which refer to classic human theories).

Human knowledge remains particular. Our linguistic theories evolve like biological (holo)bionts and demonstrate "universal symbiogenesis" by stitching and patching old ideas together into new ones (Gontier 2007). But many ideas remain unrooted in niches, or they are dissociated with the multiple realities life's biodiversity builds and embodies. At most, they are part of our brain, or we extend them into books or into an extended or global mind such as the internet.

Because many of our ideas and theories are unrooted, they are prone not to be true or only partially true. But that does not take away from the fact that they are real for those who believe in them, which is why they are so dangerous sometimes. Ideas are very powerful. We are a species that kills over ideas.

Instead of holding them true, we should remember that our outlook is limited by our current and historically grown knowledge and it is biased toward our particular bio-reality that contains our particular cultures and languages. Progress therefore depends upon comparing different views to one another and to finding alternative instrumental ways to look at our surroundings. Other (holo)bionts and different worldviews can help with that, and we can find a moderate progress in how we are catching up with the old realities of the living world.

Much depends upon preservation because many ideas, not only the bad ones, are lost. Ideas can only survive when they are continuously transmitted. But while today so much funding goes toward conservation of biodiversity, little attention is given to the conservation of valuable ideas. Instead, projects get funded based upon innovation which carries within it the idea that everything said and done before is false. It turns scholars away from the past in search for a future, while the past has brought us here and is therefore more real than what has yet to come. In Nietzsche's wake, we can sit back and be jolly about how much of science involves a reinvention of the wheel because it does not care for history.

The ancients knew the importance of the past, and they used it to understand the present and to predict the future. They were not wrong when they found *cyclic patterns* in the return of the planets, the seasons, and the constellations. They just understood it from within their geocentric worldview, wherefrom we have since evolved. They were also not wrong in finding returning cycles of coming and becoming or generation and decay, they just did not know that outside perturbations could alter the chain of events trough, e.g. mutations. But altering the chain or not, all life and perhaps the entire multiverse continues to generate and decay. That is most certainly true and one of the biggest insights that comes from the ancient schools. Much of ontogenetic, phylogenetic and paleontological work nowadays involves a return to research on recurring cycles (Gontier 2016b). We find them in how the Darwinian principles repeat each generation anew, in how DNA translates into proteins through RNA, how organs develop in the body, how circadian rhythms evolve, how holobionts form, and perhaps even speciation and extinction events follow recurring periodicities. Many of these cycles now take on the form of *networks*.

Judeo-Christians were also not wrong by understanding that many events that characterize history are unique. It made them linearize time and attempt to develop chronologies. Natural history scholars were also not wrong when they continued these traditions and mapped the history of life as going from genes, to single cells to multicellular (holo)bionts, from fish to reptiles and mammals. Where they went wrong is that they assumed that this linear sequence of events is fixed, because today we know that unicellular bionts can penetrate multicellular ones and create holobionts. Symbioses jump between lineages in spacetime, and viruses and bacteria appear to travel through spacetime at the blink of an eye. None of it requires a rewinding of past events. Instead, it demands concepts of downward and horizontal inter-hierarchy causation, as well as non-linear dynamics; and it shows that chronologies are one-sided views that "merely" focus on the historical trajectory of one particular dataset.

Natural history scholars were also not wrong when they said that European culture evolved from hunter-gathering to agriculture to industrial and technological communities. Where they went wrong is that they assumed this was a natural order or prototype by which all cultures evolved. What they should have done instead, is realize that much of our current society continues to depend upon agriculture and industry, and they should have analyzed the particular histories of other cultures, and compare them to one another (Pinxten 1997).

Much of the phylogenetic ramifications that occurred within the trees of life, languages and cultures can now be proven by gene comparisons of living (holo) bionts and even, in some cases, ancient DNA retrieved from fossils. One of the things that came out of that is that we humans not only are a single species, cultural and linguistic phylogenetics proves that we have never been isolated into a homeland, with a home language and a home culture. Human populations have always crossed paths. They exchanged genes, microbes, animals, plants, humans, ideas, words, and material artifacts. That there once used to be isolate cultures is a false nationalist idea of the 19th and early 20th century that has no ground in reality.

The modern synthesis was also not wrong when it claimed that evolution occurs by means of natural selection. The problem is that they only provide one side of the evolutionary story, and they failed to see how drift, macroevolutionary theory, symbiology, ecology, and ontogeny or epigenetics identify key players in evolution.

While a moderate case can be made for progress in the sciences, we also need to come to terms with the fact that there is not one truth out there. Truth changes with time and space, and epistemologically, a pluralistic account should be favored. The question is not who is right or wrong, but how distinct insights from different human and organismal cosmologies together provide a deeper understanding of the complex and multiple realities that life has evolved up until today, and how we can move forward from there. Pluralistic schools go back to scholars such as James (1909), the American anthropologists including Kroeber and Boas, and the American pragmatists.

Concluding Remarks

The consequences of accepting that epistemology or knowledge comes and goes with the (holo)bionts that evolve it, is that it questions the existence of a single world or level within that world that is more real. Instead, it recognizes reality and truth as variable and evolving over time. At one point in time, we know that earth was a dead planet, but ever since life evolved, that planet has changed inside out by the (holo)bionts that inhabit it. Life recycles the once dead planet into a living one.

Knowledge comes and goes with the organisms that contract and expand in space and time. What is true for one (holo)biont, is not true for another. These (holo)bionts extend their knowledge into their progeny and onto their surroundings thereby altering it into the currently living earth. The ontological state of the world changes inside out.

In such a cosmology, there is no room for adaptationist accounts, for uniformitarianism or physicalism. If there once was an abiotic physical world, we evolved from it. There is also no room for reasons or causes that explain why things are as they are. There are only processes that involve phenomena bringing forth other phenomena. Such a view most certainly has room for free will, one that takes into account all the living, if we want to.

Finally, whether or not the above outlines for a new cosmology are true or false, or better useful, I leave to the reader. In our everyday lives, we do not need metaphysics. One might even say that it is heavy on the mind and perhaps unhealthy. We should not roam in our thoughts too much. So proceed, all is well and everything around you is real, even if you don't see the cells that make you up, or the underlying particles they are composed of. They appear to know what they are doing, sometimes better than your conscious self. We have evolved to live in this world we see around us, and we can, with a significant amount of moderation, and most of all by considering that others are just like us, trust our bodies.

But what then, do we do when in doubt? Descartes, for example, in his period of doubt about the truths of the world, compared it to being stuck in a forest. To find your way out, and quite consistent with his mathematics, he advised to keep a straight line. Later he went on to say that he could think his ideas and that because he thought them, they were real. He also added they were a gift from a benign God. His *cogito ergo sum* brought forth the phenomenological and cognitive sciences.

Truth is that when you keep a straight line in a forest, you keep bumping into the trees that form part of that reality right then and there. You might slip into a pond, get chased by some animals, get bitten by ticks, end up with some kind of lifelong disease transmitted in the bite, and get soaked by a tropical thunderstorm our kind induced due to global warming. When in doubt, give it a try, that's how real it gets.

The new cosmology also comes with an invitation, to open our minds to other and new ideas, to learn and to show respect for other views, because we cannot make things happen on our own. And we should realize that ideas, however beautiful, can also be destructive. People kill each other and themselves in the name of ideas daily. But in the end, they are just ideas, real for you but not necessarily for someone else. They are furthermore prone to change over time and with the generations that think them and that will remodel them anyway, and that should be encouraged. The availability of alternative frames of reference brings forth flexibility in deploying them which is virtuous because it gives freedom. Socioculturally and politically, we can step outside our local niches and learn from others, try to get along and build a better future for us all.

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References

B.P. Abbott, LIGO Scientific Collaboration and Virgo Collaboration et al., Observation of gravitational waves from a binary black hole merger. Phys. Rev. Lett. **116**, 061102 (2016)

E. Anderson, *Introgressive Hybridization* (Wiley, New York, NY, 1949)

H. Arendt, *The Human Condition* (University of Chicago Press, Chicago, IL, 1958)
J. Barnes, *The Complete Works of Aristotle* (Princeton University Press, Princeton, 1984)
G. Barsanti, *La scala, la mappa, l'arbero: Immagini e classificazioni della natura fra Sei e Ottocento* (Sansoni, Firenze (Italy), 1992)
W. Bechtel, *Philosophy of Science* (Lawrence Erlbaum Association, Hillsdale, NJ, 1988)
W. Bechtel, Mechanism and biological explanation. Philos. Sci. **78**, 533–577 (2011)
P. Bourdieu, *Outline of a Theory of Practice* (Cambridge University Press, Cambridge, MA, 1977)
M. Bradie, Assessing evolutionary epistemology. Biol. Philos. **1**, 401–459 (1986)
M. Bradie, *Evolution and Culture*. (2017) https://doi.org/10.1002/9780470015902.a0027505
D. Campbell, Evolutionary Epistemology, in *The Philosophy of Karl Popper*, vol. 1, ed. by P. Schilpp (La Salle, Chicago, IL, 1974), pp. 413–459
F. Ciccarelli, T. Doerks, C. von Mering, C.J. Creevey, B. Snel, P. Bork, Toward automatic reconstruction of a highly resolved tree of life. Science **311**(5765), 128–1287 (2006)
A. Clark, D. Chalmers, The extended mind. Analysis **58**, 7–19 (1998)
C.F. Craver, W. Bechtel, Top-down causation without top-down causes. Biol. Philos. **22**, 547–563 (2007)
C. Darwin, *The Origin of Species* (Murray, London, 1859)
R. Dawkins, Universal Darwinism, in *The Philosophy of Biology*, ed. by D. Hull, M. Ruse (Oxford University Press, Oxford, 1983), pp. 15–35
R. Dawkins, *The Extended Phenotype* (Oxford University Press, Oxford, 1989)
N. Eldredge, *Unfinished Synthesis: Biological Hierarchies and Modern Evolutionary Thought* (Oxford University Press, New York, 1985)
H. Everett, Relative state formulation of quantum mechanics. Rev. Mod. Phys. **29**(3), 454–462 (1957)
V. Faria, E. Sucena, Novel endosymbioses as a catalyst for fast speciation. In N Gontier (ed) Reticulate Evolution (Dordrecht, Springer, 2015) pp. 107–120
J.F. Ferrier, *Institutes of Metaphysic the Theory of Knowing and Being* (William Blackwood and sons, Edinburgh, 1854)
M. Ghiselin, A radical solution to the species problem. Syst. Zool. **23**(4), 536–544 (1974)
A. Goldman, *Simulating Minds* (Oxford University Press, Oxford, 2006)
N Gontier, *Evolutionary Epistemology. Internet encyclopedia of Philosophy* http://www.iep.utm.edu/evo-epis/ (2006)
N. Gontier, Universal symbiogenesis: an alternative to universal selectionist accounts of evolution. Symbiosis **44**, 167–181 (2007)
N. Gontier, Evolutionary epistemology as a scientific method: A new look upon the units and levels of evolution debate. Theor. Biosci. **129**, 167–182 (2010)
N. Gontier, Depicting the tree of life: the philosophical and historical roots of evolutionary tree diagrams. Evol. Educat. Outreach **4**(3), 515–538 (2011)
N. Gontier, Applied evolutionary epistemology: a new methodology to enhance interdisciplinary research between the human and natural sciences. Kairos **4**, 7–49 (2012)
N. Gontier, Reticulate evolution everywhere, in *Gontier N*, ed. by Reticulate Evolution (Springer, Dordrecht, 2015a), pp. 1–40
N. Gontier, Uniting micro- with macroevolution into an extended synthesis: Reintegrating life's natural history into evolution studies, in *Macroevolution*, ed. by E. Serrelli, N. Gontier (Springer, Dordrecht, 2015b), pp. 227–275
N. Gontier, Guest-editorial introduction: converging evolutionary patterns in life and culture. Evol. Biol. **43**(4), 427–445 (2016a)
N. Gontier, Time: the biggest pattern in natural history research. Evol. Biol. **43**(4), 604–637 (2016b)
N. Gontier, What are the levels and mechanisms/processes of language evolution? Lang. Sci. **63,** 12-43 (2017)
N. Gontier, Pattern Similarity in Biological, Linguistic and Sociocultural Evolution. EVOLANG 12 Proceedings (World Scientific, 2018)

N. Gontier, M. Bradie, in *Acquiring Knowledge on Species-Specific Biorealities: The Applied Evolutionary Epistemological Approach*, ed. By R. Joyce. The Routledge Handbook of Evolution and Philosophy (Routledge, 2018)

S.J. Gould, R. Lewontin, The spandrels of San Marco and the panglossian paradigm: a critique of the adaptationist programme. Proc. Royal Soc. London Ser B Biol Sci **205**, 581–598 (1979)

S.J. Gould, *Ontogeny and Phylogeny* (Belknap Press, Cambridge, MA, 1977)

S.J. Gould, *Wonderful Life* (W. W. Norton, New York, 1989)

P. Griffiths, R. Gray, Developmental systems and evolutionary explanation. J Philos. **91**, 277–304 (1994)

E. Haeckel, *Athropogenie oder Etnwickelungsgeschichte des Menschen* (Engelmann, Leipzig, 1874)

B. Hallgrimsson, B. Hall (eds.), *Epigenetics* (University of California Press, Berkeley, CA, 2011)

D. Hull, *Science as a Process* (University of Chicago Press, Chicago IL, 1988)

E. Jablonka, M. Lamb, *Evolution in Four Dimensions Cambridge* (MIT Press, MA, 2006)

W. James, *A pluralistic universe* (Longmans, London, 1909)

T. Kuhn, *The Structure of Scientific Revolutions Chicago* (Chicago University Press, IL, 1962)

I. Lakatos, *The Methodology of Scientific Research Programmes Cambridge* (Cambridge University Press, MA, 1978)

K. Laland, J. Kumm, M. Feldman, Gene-culture co-evolutionary theory. Curr. Anthropol. **36**, 131–146 (1995)

L. Laudan, Progress and its Problems: Towards a Theory of Scientific Growth. University of California Press (1977)

R. Levins, R.C. Lewontin, *The Dialectical Biologist* (Harvard University Press, Cambridge, MA, 1985)

R. Lewontin, The levels of selection. Annu. Rev. Ecol. Syst. **1**, 1–18 (1970)

R. Lewontin, Adaptation. Sci. Am. **239**, 157–169 (1978)

R. Lewontin, Organism and environment, in *Learning, Development and Culture*, ed. by H. Plotkin (Wiley, New York, NY, 1982), pp. 151–170

R. Lewontin, *The Triple Helix* (Harvard University Press, Cambridge, MA, 2000)

K. Lorenz, Kant's lehre vom apriorischen im lichte gegenwärtiger biologie. Blätter für Deutsche Philosophie **15**, 94–125 (1941)

A.O. Lovejoy, *The Great Chain of Being* (Harvard University Press, Cambridge, 1936)

J.E. Lovelock, L. Margulis, Atmospheric homeostasis by and for the biosphere: the Gaia hypothesis. Tellus, Series A, Stockholm: International Meteorological Institute **26**(1–2), 2–10 (1974)

L. Margulis, D. Sagan, *What is Life?* (University of California Press, Berkeley, CA, 2000)

L. Margulis, Symbiogenesis and symbionticism, in *Symbiosis as a Source of Evolutionary Innovation*, ed. by L. Margulis, R. Fester (MIT press, Cambridge, MA, 1991), pp. 1–14

J. Maynard Smith, E. Szathmáry, *The Major Transitions in Evolution* (Oxford University Press, Oxford, NY, 1995)

J. Maynard Smith, Group selection and kin selection. Nature **201**(4924), 1145–1147 (1964)

M. McLuhan, *Understanding Media* (McGraw Hill, New York, NY, 1964)

A. Mesoudi, Cultural evolution: A review of theory, findings and controversies. Evol. Biol. **43**(4), 481–497 (2016)

P. Munz, *Philosophical Darwinism* (Routledge, London, 1993)

F. Odling-Smee, Niche Constructing Phenotypes, in *The Role of Behavior in Evolution*, ed. by H. Plotkin (MIT, Cambridge, MA, 1988), pp. 73–132

S. Okasha, Multilevel selection and the major transitions in evolution. Philos. Biol. **72**, 1013–1025 (2005)

M. Pigliucci, An extended synthesis for evolutionary biology. The year in evolutionary biology 2009. Ann. N. Y. Acad. Sci. **1168**, 218–228 (2009)

R. Pinxten, *When the Day Breaks* (Peter Lang, Frankfurt am Mein, 1997)

K. Popper, *The Poverty of Historicism* (Routledge, London, 1957)

K. Popper, *Conjectures and Refutations* (Routledge & Keagan, London, 1963)

K. Popper, *Objective Knowledge* (Clarendon Press, Oxford, 1972)
K. Popper, Critical Remarks on the Knowledge of Lower and Higher Organisms, the So-Called Motor Systems, in *Sensory Motor Integration in the Nervous System*, ed. by O. Creutzfeldt, R. Schmidt, W. Willis (Verlag, Dordrecht, 1984), pp. 19–31
I. Prigogine, *From Being To Becoming* (Freeman, New York, 1980)
W.V.O. Quine, Two dogmas of empiricism. Philos. Rev. **60**, 20–43 (1951)
C.R. Reid, T. Latty, A. Dussutour, M. Beekman, Slime mold uses an externalized spatial memory to navigate in complex environments. PNAS **109**(43), 17490–17494 (2012)
R. Riedl, *Biologie der Erkenntnis: Die stammesgeschichtlichen Grundlagen der Vernunft* (Parey, Berlin, 1980)
A. Riegler, Like cats and dogs: radical constructivism and evolutionary epistemology, in *Evolutionary Epistemology, Language and Culture*, ed. by N. Gontier, et al. (Springer, Dordrecht, 2006), pp. 47–65
M. Rowlands, *The New Science of The Mind: From Extended Mind to Embodied Phenomenology* (MIT Press, Cambridge, MA, 2010)
M. Ruse, The View from Somewhere: A Critical Defense of Evolutionary Epistemology, in *Issues in Evolutionary epistemology*, ed. by K. Hahlweg, C.A. Hooker (State University of New York Press, Albany, NY, 1989), pp. 185–228
M. Sahlins, *Evolution and Culture* (University of Michigan Press, Ann arbor, MI, 1970)
E. Sapir, Do we need a 'superorganic'? Am. Anthropol. **19**, 441–447 (1917)
B.F. Skinner, The evolution of verbal behavior. J. Experiment. Anal. Behav. **45**, 115–122 (1986)
L. Smolin, *The Life of the Cosmos* (Oxford University Press, New York, NY, 1997)
H. Spencer, *The Principles of Sociology* (Williams and Norgate, London, 1876)
I. Stewart, *The Mathematics of Life* (Basic books, New York, NY, 2011)
Stich From Folk Psychology to Cognitive Science (Cambridge, MA, MIT Press, 1983)
I. Tëmkin, N. Eldredge, Networks and hierarchies: approaching complexity in evolutionary theory, in *Macroevolution*, ed. by N. Gontier, E. Serrelli (Springer, Dordrecht, 2015), pp. 227–275
S.H. Toulmin, Understanding Princeton. NJ: Princeton University Press translated by J. Churchill. (The Hague: Martinus Nijhoff, 1972)
L. Van Valen, A new evolutionary law. Evol. Theor. **1**, 1–30 (1973)
L.P. Villarreal, G. Witzany, Viruses are essential agents within the roots and stem of the tree of life. J. Theor. Biol. **262**(4), 698–710 (2010)
T. Volk, *Quarks to culture: how we came to be* (Columbia University Press, New York, NY, 2017)
A.N. Whitehead, *Process and reality, Gifford lectures 1927–1928* (Cambridge University Press, Cambridge UK, 1929)
R.A. Wilson, Collective memory, group minds, and the extended mind thesis. Cogn. Process. **6**, 227–236 (2005)
G. Witzany, *Biocommunication of Animals* (Springer, Dordrecht, 2014)
L. Wolpert, *How We Live and Why We Die* (W. W. Norton & Company, New York, NY, 2009)
F. Wuketits, Evolutionary epistemology: The non-adaptationist approach. In N. Gontier, van Bendegem JP Aerts D (eds) Evolutionary Epistemology, Language and Culture pp. 33–46 (Dordrecht, Springer, 2006)
V.C. Wynne-Edwards, *Evolution Through Group Selection* (Blackwell, Odford, 1986)
O. Zhaxybayeva, W.F. Doolittle, Lateral gene transfer. Curr. Biol. **21**(7), R242–R246 (2011)