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Review article

RECONSTRUCTING ANAXIMANDER'S BIOLOGICAL MODEL UNVEILS A THEORY OF EVOLUTION AKIN TO DARWIN'S, THOUGH CENTURIES BEFORE THE BIRTH OF SCIENCE

REKONSTRUKCIJA ANAKSIMANDAROVA BIOLOŠKOG MODELA RAZOTKRIVA TEORIJU EVOLUCIJE SRODNU DARVINOVOJ, IAKO STOLJEĆIMA PRIJE ROĐENJA ZNANOSTI

Siro Igino Trevisanato*

Summary

Anaximander's fragments on biology report a theory of evolution, which, unlike the development of other biological systems in the ancient Aegean, is naturalistic and is not based on metaphysics. According to Anaximander, evolution affected all living beings, including humans. The first biological systems formed in an aquatic environment, and were encased in a rugged and robust envelope. Evolution progressed with modifications that enabled the formation of more dynamic biological systems. For instance, after reaching land, the robust armors around aquatic beings dried up, and became brittle, This led to the loss of the armor and the development of more mobile life forms. Anaximander's theory combines observations of animals with speculations, and as such mirrors the more famous theory of evolution by Charles Darwin expressed 24 centuries later. The poor reception received by Anaximander's model in his time, illustrates a zeitgeist that would explain the contemporary lag phase in the development of biology and, as a result, medicine, in the ancient western world.

Key words: *Anaximander; Darwin; Santorini eruption; theory of evolution.*

* *Correspondence address:* Siro Igino Trevisanato, SUM-MUS Communications, 433-4000 Yonge Street, Toronto, ON M4N 2N9, Canada. Email: strevisa@gmail.com.

Introduction

In the first half of the 19th century, western biology mainly rested on the system developed by Aristotle (384-322 BC). In this context, species, further refined centuries later[1-2] by Carl Linnaeus (1707-1778), were understood as static, separately created, entities. The relationship among species was organized in *scalae naturae* (ladders of nature), where abiotic entities were placed on the lowest rungs, while just above them were biological systems on rocks (e.g. lichens). Climbing the ladder, biological systems exhibited more and more "animated", characteristics. At the pinnacle of the ladder was humankind[2].

Charles Darwin (1809-1882) questioned the static understanding of biological systems and their metaphysical foundation. Simplifying Darwin's work, members of species presented a distribution of traits; Darwin hypothesized that as diverging traits accumulated, differences among individuals became more pronounced. At some point, such an accumulation would have produced individuals radically different from the average ones in the species, placing them in species of their own[3].

Darwin's model was dynamic, not linked to metaphysics, and accepted by the contemporary zeitgeist. For instance, as early as 1866, and just a few years after the divulgation of Charles Darwin's theory of evolution, Ernst Haeckel, using *scalae naturae* and Darwin's own tree of life, chronologically branched out named species[4], and therefore established what would be later known as phylogenetic trees[5].

Darwin's model paved the way for further developments in biology (e.g. determination of data determining traits, its transmission and expression[6-7]), and as a result, in medicine[8].

Ancient Aegean science

Aristotle (384-322 BC), who statically classified empirical observations, and tethered them to his metaphysical principle, shaped biology for centuries to come until the time of Darwin. Aristotle came from the ancient Aegean, a world that understood the universe to be grounded in metaphysics[2], and thus in principle(s), which, independent of bonds (e.g. time and space), generated the rest of reality.

Aegean tradition had apparently formulated a dynamic perspective on biological systems. In early times, *mýthoi*, which recounted facts and/or phenomena as parts of theophanies, often reported metamorphoses. Males

turned into females and females into males (Ovid, *Metamorphoses*, 9.666-797, Hyginus, *Fabulae*, 75)[9-10], people turned into bears (Apollodorus, *Library*, 3.8)[11], birds (Ovid, *Metamorphoses*, 6.424-674, Hyginus, *Fabulae*, 45)[9-10], dolphins (Hyginus, *Fabulae*, 134)[10], and trees (Pausanias, *Description of Greece*, 8.20)[12], gods turned into horses (Pausanias, *Description of Greece*, 4.25)[12], and precipitations (Apollodorus, *Library*, 2.34)[11]. One Proteus managed to turn into a lion, a snake/dragon, a leopard/panther, a pig, water and a tree (*Odyssey*, 4.450-460)[13].

By classical times, the Aegean zeitgeist had moved away from understanding reality in terms of *mýthoi*, and, while keeping its weltanschaaung grounded in metaphysics, favored a *lógos*-based explanation using logic (e.g. law of non-contradiction) and perception through the senses.

Thus, Heraclitus of Ephesus (roughly 535-475 BC) proposed a universe where antagonist forces (rather than gods) produced changes according to *lógos* (Heraclitus fragments 1-2, and 72), as seen in several natural processes (Heraclitus fragments 31, 61, 76, 90, and 126)[14].

Anaximander's theory of evolution

Anaximander of Miletus (roughly 610-545 BC), having studied under 6th century BC philosopher Thales (Anaximander fragment 2)[14], is credited with being the first western philosopher to commit his work to writing, though only fragments survived in quotations by various authors. Anaximander saw the universe grounded in metaphysics (Anaximander fragment 1)[14], whereby entities arose and ended within a frameless frame called *ápeiron* (boundless Absolute) through which the entities paid back the unjust actions done throughout their existence (Anaximander fragment 9)[14].

Anaximander also proposed that biological systems developed. His proposal was deemed to fit his *ápeiron*-based universe[15], and to constitute a speculative theory of evolution[16]. However, neither claim took into consideration a scenario that integrated all Anaximander's pertinent fragments, i.e. 2, 9, 15, 27 and 30[14].

The reconstruction of the full scenario, not done to our knowledge prior to the present communication, shows that the first living beings formed in the original water, which is not a metaphysical principle as proposed by his teacher Thales (Anaximander fragment 2 and 9)[14]. That original water was a mass that disappeared unidirectionally, and let submerged lands, emerge

(Anaximander fragment 27)[14]. At this stage, living beings sported a solid and rugged envelope, were already developing. For instance, among these early biological systems was the ancestor of humans, which had developed a feature that would be transmitted to modern humans, i.e., the necessity of rearing the offspring up to adolescence, a feature that could still be observed in contemporary aquatic biological systems such as some sharks. Later, aquatic beings, which had already started to differentiate in the water, were caught in an area, where the evaporation from the sun changed shallow waters into dry land. As a result, the solid envelope of the aquatic beings dried up, became friable, and broke; the now more flexible biological systems *metabiōnai*, i.e. went beyond their way of life, and quickly adapted to life on land (Anaximander fragment 30)[14].

Naturalism in Anaximander *metabiōnai* theory of evolution

Anaximander's biological model was not linked to gods[16], a point that can be easily seen by juxtaposing his system to standard Aegean ones. A saga, which reports the formation of humankind, and which claimed to have Aegean origin (*Prose Edda, Prologue*)[17] ensures a sound, "apple-to-apple", comparison.

In the saga, three gods found two tree trunks along the shore. One god gave life and a life span to the items, another god gave motility and thinking skills to the breathing timber, and finally, the third god added outer features by carving the wood, as well as the ability to smell, taste, etc. The two beings thus derived were the first humans (*Prose Edda, Gylfaginning*, 9)[17].

In spite of shared items between Anaximander's model and the Nordic story, such as life being formed, entities clad in a tough envelope, a coastline, and acquisition of traits, Anaximander's model presents no characteristics derived from metaphysics. Instead, it derives all biological systems, including humans, off one source as naturalistically as possible in a pre-scientific context.

Furthermore, Anaximander's *metabiōnai* model lacks a metaphysical principle, a feature that made no sense in the ancient western zeitgeist. In fact, a quotation by Plutarch (45-120) that forms Anaximander fragment 30[14] states that the *Syroi* (Syrians), who claimed that fish and men were part of the same phase of the cosmogony, made sense to him, unlike Anaximander's proposal!

Finally, elements in Anaximander's biological theory point to empirical data. His first aquatic beings have a rocky appearance like bivalves, crustaceans, echinoderms and sea horses. The first terrestrial beings shed the rocky appearance, possibly inspired by "amphibian" reptiles, which like crocodiles and turtles "sprouted" limbs where there was no tough skin or shell.

The loss of the armor also makes sense on the basis of observations: hydrated structures, once dried, tend to be brittle. Furthermore, moulting, the loss of the outer perimeter of an animal, is a known phenomenon in snakes, lizards, amphibians and crabs. The naked biosystem left on land could have been likened to an armoured tadpole emerging from dried mud, and becoming a frog.

A possible source for the Anaximander theory of evolution

The *metabiōnai* model is so different from other Aegean models rooted in metaphysics, that it may point to a time of serious breakdown in the society, which compelled, or inspired, someone to think radically differently. Anaximander's biological model may therefore have been formulated by an earlier author, and was then reported by Anaximander, which would explain the co-presence of two incompatible systems in Anaximander's work.

The most drastic event impacting the Aegean was the Santorini eruption, one of the largest eruptions known, which took place at the end of the 17th century BC[18]. The resulting tsunamis[19], ash, ash-derived health problems (burns from acids, abrasion of cornea, respiratory problems, pregnancy complications, psychological traumas), ash-related meteorological perturbations (acid rain, more frequent precipitations, lower temperatures), and effects thereof (malnutrition)[20-22] radically modified the geopolitical and cultural landscape of the eastern Mediterranean[22].

Santorini eruption data are known to have been passed via *mýthoi*. One set of data is the "flight" of Giantess Leto. Unable to rest on ground, coherently with a volcanic cloud, Leto changed the color of waters, compelled amphibians to leave their habitat, and caused famine, all phenomena coherent with the fallout of volcanic ash[20, 23]. Finally, Leto's itinerary from the Aegean to the Nile Delta matches the path of residues of Santorini ash[20].

Santorini eruption data also appear in philosophers' works. Pherecydes of Syros (roughly 580-520 BC), retold a Santorini-based cosmology, and

Heraclitus of Ephesus (roughly 535-475 BC), reported information on the dynamics of the eruption[20]. Even Anaximander rpovides such data: his fragments 10 and 18 describe a world emerging out of fire from a tree in an area with circles[14], consistently with volcanic activity in a complex of craters.

Pre-Santorini eruption Aegeans, who survived the event would have noticed life forms reclaiming the leftover land mass.

In fact, colonization of areas sterilized by volcanic eruptions show how little time is needed for life forms to return to areas affected by the eruption.

Pollen retrieved in the sediments of Gölhisar Lake, Anatolia, shows that ash from the Santorini eruption destroyed the local vegetation 300 km away for 6 to 7 years after the eruption. Thereafter, the deposited volcanic material promoted the growth of vegetation in and around the lake[24].

At Krakatau (also known as Krakatoa), the large eruption of 1883 extirpated all local life forms on Rakata, Sertung and Panjang, the islands remaining after the eruption. Thereafter, reptiles and rats were already observed on these very islands in 1889, land birds were observed in 1908, and bats were observed by 1924. In the interim, vascular plants had colonized the site[25].

However, colonization data of sites affected by eruptions do not show Santorini eruption data in Anaximander's biology model. Plants are conspicuously absent from Anaximander's model. Yet, plants are paramount in the colonization process as they support the presence of other species, and would have been introduced by flying birds through soil and feces contaminated with grains and spores.

Additionally, the first terrestrial animals to reach post-eruption Santorini would have been nearby land animals, ferried on boats, floating on drift wood, or swimming, rather than amphibians or morphing aquatic biological systems.

Furthermore, Anaximander's receding waters, which would have enabled marine biological systems to switch to a different lifestyle, do not conform to the remaining parts of Santorini after the eruption.

Finally, there were no new biological systems at Santorini[26], only systems that had existed earlier or had lived nearby. Such an event could not have inspired the *metabiōnai* model proposed in Anaximander's work, and thus, one must discard a Santorini-based origin.

Conclusion

The reconstruction of the *metabiōnai* biological model presented by Anaximander from the extant fragments of his work shows that the philosopher of Miletus provides the oldest known recorded model for evolving biological systems within a naturalistic context. Anaximander may not have authored the model, which is incompatible with his philosophical model. However, a brief search for alternative sources for the *metabiōnai* model proved negative.

The *metabiōnai* model breaks away from non-naturalistic systems characteristic of the ancient Aegean.

Unlike Aegean stories reporting the formation of humankind, as exemplified by the aforementioned saga, Anaximander's biological model does not rely on gods[17].

Anaximander's *metabiōnai* model also breaks away from metaphysical principles, such as the one represented by water, and espoused by his master Thales. In Anaximander's model, water is not a principle, but rather a physical mass, which covers another physical mass, soil. In so doing, soil was independent of the aforementioned series of crimes and punishments in the ápeiron, challenging Anaximander's metaphysical model.

The formation of life is understood by Anaximander to be spontaneous, and to take place at the interface of surfaces or masses. This point can be deduced by terrestrial life forms reaching land not because they beach themselves or crash because of rising waters, but because ever-shallower pools turned into mud, which turned into soil, trapping the biological systems on dry land.

Applying the same logic to the aquatic beings, such biological systems would have formed at the interface between the water and the soil, at the bottom of the sea, giving rise to living beings that looked like rocks, and then changed to less rigid, armored aquatic beings.

Anaximander also appears to state that changes to biological systems take place all the time. In fact, while some aquatic beings that developed a rearing trait, ended up trapped in disappearing lagoons and then mud, and through several changes became quasi-hairless two-legged-walkers on dry land, other aquatic armor-clad rearing beings that stayed in the sea followed a different path, shedding their armour, and turned into a form of sharks.

Finally, the engine behind Anaximander's model appears to reside in the ability to become more mobile. For instance, the first terrestrial beings lost a ballast, the armor, thus becoming faster and more flexible.

Such a model derived all biological systems off one original source of life, without divine intervention. Changes to these systems were within naturalistic frame (considering that spontaneous generation was accepted at the time). Thus, the model was based on empirical data available at the time, and is akin to the theory of evolution by Charles Darwin, who centuries after Anaximander, also reflected on empirical observations available in his time.

However, unlike Darwin's 19th century theory of evolution, Anaximander's mid-5th century BC theory was premature for its culture unable to naturalistically look at biosystems, thus postponing the development of biology and correlated achievements[2].

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Sažetak

Anaksimandarovi fragmenti o biologiji izvješćuju o teoriji evolucije, koja je, za razliku od razvitka drugih bioloških sustava na drevnom egejskom prostoru, naturalistička i nije temeljena na metafizici. Prema Anaksimandaru, evolucija je zahvatila sva živa bića, uključujući ljude. Prvi biološki sustavi formirani su u vodenom okolišu te su bili oklopljeni u hrapav i robustan oklop. Evolucija je progredirala s modifikacijama koje su omogućile nastajanje dinamičnijih bioloških sustava. Primjerice, nakon prelaska na kopno, robustan oklop oko vodenih bića isušio se i postao lomljiv. To je vodilo gubitku oklopa i razvoju pokretnijih oblika života. Anaksimandarova teorija kombinira opservaciju životinja sa spekulacijom i kao takva odražava poznatiju teoriju evolucije Charlesa Darwina, objavljenu 24 stoljeća kasnije. Slabo prihvaćanje Anaksimandarova modela u njegovo vrijeme ocrtava duh vremena koji bi mogao pojasniti onodobni usporeni period razvoja biologije te, kao posljedica toga, medicine antičkog zapadnog svijeta.

Ključne riječi: *Anaksimandar; Darwin; erupcija na Santoriniju, teorija evolucije.*