Discover Life

Comment

2500 years ago scientific theories of the origin of life arose in ancient Greece

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Received: 8 January 2024 / Accepted: 27 March 2024
Published online: 10 April 2024

Abstract
What have the Greeks ever done for us? Everything. This short commentary celebrating the earliest history of origin of life research seeks to bring to the attention of the community of origin of life researchers that there is a much longer tradition of scientific theories in this subject than some people are aware of; there are 2500 years of thinking that we should not forget about. In Ionian Greece, Thales initiated ideas that we can see as the beginnings of science itself. Anaximander, his pupil, was particularly interested in the origins of the world, including how life had arisen, and proposed a species of proto-evolutionary theory of the origin of life. 2500 years ago, Anaxagoras left Ionia for Athens taking ideas of scientific thinking with him. Anaxagoras is credited with being the originator of a further theory of the origin of life, that of panspermia. The scientific conception of knowledge was attacked almost immediately, and Anaxagoras ended up exiled, but that idea of the knowability of things survived and led, many centuries later, to the scientific revolution and to our current human civilization.

1 The Greek origins of science

Anaxagoras (c. 500 to c. 428 BCE), from Clazomenae in Ionia, seen in Fig. 1 holding the globe, was the first scientist to live and work in Athens. Before Anaxagoras, science in the ancient Greek world had been carried out across Ionia—the Mediterranean coast of Asia Minor, today's Turkey—but not in what is modern Greece itself. In the Ionian city of Miletus Thales, followed by Anaximander and Anaximenes, had a few decades earlier begun science itself. Anaxagoras carried those ideas to Athens with him from Ionia, while another Ionian, Pythagoras, moved to what is today southern Italy and took science with him there, too [2]. The very concept of science was developed in Miletus by Thales—perhaps the first scientist—and Anaximander, whose idea of the Earth being suspended in space Popper described as "one of the boldest, most revolutionary, and most portentous ideas in the whole history of human thought" [3]. As Rovelli [4] has recently argued, they changed the world not only with their material, rather than divine, explanations for phenomena, but also with the scientific method of being able to disagree and to improve a theory. Anaxagoras "introduced the scientific spirit into Athens" [5] in its Golden Age. We now term Thales, Anaximander, Anaximenes, and Anaxagoras 'pre-Socratic' philosophers, as Socrates, Plato, and, most of all, Aristotle established for future generations Athens' pre-eminence at the centre of philosophical thought. However, they also discarded their Ionian predecessors' scientific approach to the universe: they brought religion back.

Although it is possible that Anaxagoras and Socrates, thirty years his junior, could have met in Athens, the established academic line is through Archelaus [6]. The biographer Diogenes Laertius wrote in the third century CE that Archelaus

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Fig. 1 A nineteenth century depiction of ancient Athens. Fresco on the facade of the historic building of the University of Athens, begun by Carl Rahl in the 1860s and finished by Eduard Lebiedzki, c. 1888. Left: in this segment we see Pericles, Aspasia, Plato, Antisthenes, and Anaxagoras. Right: detail from the Athens fresco. Anaxagoras is depicted holding the Earth. Since it is shown all blue, it is not much of a stretch to think it is a waterworld phase of the early Earth, precisely when life might have got started [1] (to be clear, of course that idea was not in the mind of the artist, but is my contemporary interpretation)

had been "student of Anaxagoras, teacher of Socrates" [7]. In turn, Plato was a student of Socrates, and Aristotle was a student of Plato. And until the renaissance—when Raphael painted The School of Athens, seen in Fig. 2 caused scholars to go back and study what remained of all these people's work, it was Aristotle's influence that dominated. Aristotle was followed, often blindly, for the next fifteen centuries or so until the next scientific revolution, that of Copernicus, Kepler, Galileo, and Newton.

2 Anaxagoras' Athens

We pesky scientists, always asking awkward questions and getting into trouble from politicians who would rather not hear. This sounds like today, but it was also Athens, 2500 years ago. When, 2500 years ago, Anaxagoras arrived in Athens and began discussing these ideas, he was eventually thrown out of the city for 'impiety'. We know that he lived in Athens for 30 years, but it is uncertain whether this was beginning in his twenties, from 480 BCE onwards [8], or his forties, from around 460 BCE onwards [9]; for comparison, the construction of that emblematic building of Athenian and Greek culture, the Parthenon, began, ordered by the Athenian politician Pericles, in 447 BCE, 2469 years ago.

It should come as no surprise that Anaxagoras ran into problems for his emphasis on natural explanations and disinterest in the gods. Authorities in Athens accused him of impiety, found him guilty, and sentenced him, according to some accounts, to death, according to others 'only' to prison. Anaxagoras' friend Pericles intervened and arranged that he go into exile instead of these fates. Thus Anaxagoras lived at the end of his life in Lampsacus in what is now northwest Turkey. Socrates, some decades later, was sentenced to death in Athens precisely for following this lead, for 'impiety' and 'corrupting youth', and that sentence was enforced. So the Ionian experiment in scientific thinking was strangled for centuries [9] as Plato and Aristotle placed their philosophical ideas within a divine context.

The image in Fig. 1 is from a fresco painted in the nineteenth century to decorate the facade of the new central building of the then recently founded University of Athens. It depicts a scientific meeting organized 2500 years ago in Athens by another Ionian, Aspasia of Miletus. We see Anaxagoras and Pericles, and—anachronistically—Antisthenes and Plato, attending Aspasia's salon in Athens. Aspasia of Miletus, friend to philosophers and Pericles' wife, was a remarkable woman,

Fig. 2 Raphael, the School of Athens, 1509–1511. A renaissance depiction of ancient Greek thinkers

perhaps the most well-known and at the same time most misunderstood woman in classical Greek antiquity. She clearly had the kind of education that most Greek women were denied, which allowed her to develop into a teacher, speaker, and thinker. To Athenians who tended to view the female ideal as the homemaker and mother without intellectual aspirations, this was anathema. Aspasia's salons were in modern terms workshops at which Anaxagoras and other thinkers developed their ideas.

What Anaxagoras attempted was to explain phenomena in an empirical, what we would call a scientific way [10]. The Roman scholar and naturalist Pliny the Elder [11], writing a few centuries later—he was born 2000 years ago in 23 CE—in the first encyclopedia, *Historia Naturalis*, describes Anaxagoras' scientific understanding of meteorite falls [12]. Anaxagoras described eclipses correctly in terms of shadows, and proposed that the Sun was not a god, but a fiery ball larger than the Peloponnese peninsula of Greece, and the stars likewise. Graham [13] writes, "Anaxagoras' choice of the Peloponnese as a unit of measurement cannot be gratuitous, but based on astronomical data", and he goes on to show persuasively that Anaxagoras based this assertion on measurements of a solar eclipse that took place across the Peloponnese in 478 BCE. As Janko [9] puts the matter, "Anaxagoras made major scientific advances that were based on empirical evidence, notably by discovering the correct explanation of eclipses and proving that the heavenly bodies are heavy material objects; he can indeed be called the true founder of science".

3 The origins of the origin of life

Anaximander is perhaps the first person with a scientific theory for the origin of life that comes down to us [14]. In his conception, the first animals appeared in a watery element. His reasoning appears to have been that life emerged from a combination of earth and water heated to a certain degree. It must therefore have started where these two elements are found together, as on the seabed or in pools [15]. All this seems very much like current theories of life's origin, where Darwin's 'warm little pond', today known as a hydrothermal pond, and seafloor hydrothermal vents are two main candidates for where on Earth life began [1].

We should also recall Empedocles [16], whose cyclic universe provided the first truly global and self-contained view of a physical universe in which combinations of a small number of basic constituents form the source of all observed

complexity. Anaximander's hypothesis of the origin of life in water was added to and shaped further by Anaxagoras, Democritus, and others. Guthrie [15] translates a longer surviving account of the theory given by Diodorus in the first century BCE:

> When the earth was first separated from the fiery heaven in the universal whirl, it was clayey and altogether soft. As the sun's fire shone down on it, it solidified. Then by reason of the warmth its surface fermented [the word used applies literally to the leavening of bread with yeast], some of the wet parts swelled up in many places, and at those places there arose centres of putrefaction surrounded by thin membranes. ... Finally when the embryos had achieved their full development, and the membranes, being thoroughly heated, had burst, all kinds of animals were born.

Anaxagoras had the revolutionary idea of the need for initial conditions of the universe. This development of Anaxagoras' thought had been in response to Parmenides, who believed that change was impossible [17]. Anaxagoras introduced nous. The word *nous*, in Greek as in English, means common sense, but in Greek it also meant a form of mind of the cosmos [15]. In the way that Anaxagoras uses the word, nous is a species of initial condition of the cosmos that sets everything off, after which the universe evolves in an almost proto-Newtonian clockwork fashion.

Anaxagoras' development of the theory of the origin of life is distinguished from Anaximander's by being concerned with the origin of life on a universal level, coming from seeds present across the cosmos. Grujić argued that Anaxagoras thought that one need not inquire about the origin of life in the global sense, just about its origin in a particular locale of the universe [18]. Theophrastus writes of Anaxagoras as saying that "the air contains the seeds of all things and that these are brought down together with the water and generate plants" [15]. That is what gets Anaxagoras labelled the father of panspermia, although his conception was very different from modern ideas of panspermia.

Panspermia is one account of the origin of life that won't go away. Modern versions of the theory posit that life arrived on Earth carried from elsewhere in the universe on meteoroids, comets, and so on. To me, although it may be correct, panspermia simply kicks this particular can (of prebiotic/primordial soup?) down the road; whether or not panspermia has occurred, we surely need to explain the first origin of this complex system that is life, whether that origin was on this planet, or somewhere else in this universe [19]. A few decades ago, Thomas Gold had an amusing and novel take on panspermia with his paper "Cosmic Garbage" (1960) in which he proposed that visiting space travellers might carelessly have discarded their rubbish while visiting the pristine Earth; trash from which we might have evolved [20]. A decade and a half later, Crick and Orgel suggested that aliens might have seeded Earth on purpose, rather than carelessly, with what they called directed panspermia [21]. These are fun thoughts, there's nothing ascientific about them, and they illustrate that panspermia, however conceived, gets us no closer to the ultimate origins of life.

4 Alife, too

The origin of life and artificial life are fundamentally intertwined. Understanding one necessarily will lead to understanding the other. Artificial life might be created as life had originally arisen. The Ancient Greeks also considered artificial life. There is an entire history of automata, self-moving machines, from Greek mythology. Homer, in the eighth century BCE, has this passage [22],

> "She found him [Hephaestus] sweating as he turned here and there to his bellows busily, since he was working on twenty tripods which were to stand against the wall of his strong-founded dwelling. And he had set golden wheels underneath the base of each one so that of their own motion they could wheel into the immortal gathering, and return to his house: a wonder to look at. These were so far finished, but the elaborate ear handles were not yet on. He was forging these, and beating the chains out."

We also have that Hephaestus fabricated Talos, a bronze giant to protect Crete from invasion, perhaps one of Hesiod's men of the Age of Bronze, described in the epic of *Jason and the Argonauts* [23], as depicted in Fig. 3. Now we might term them robots [24]. At the same time as these proto-robots were being imagined, the Greeks were building sophisticated machines such as the Antikythera mechanism [25]. The connection between these two strands, that a sufficiently complex automaton could be alive, seems to be implicit in Ancient Greek thought.

Fig. 3 Bronze sculpture of Talos, in Cambridge, UK by Michael Ayrton, 1950. A twentieth century depiction of ancient Greek conceptions of proto-robots, or artificial life

5 Epilogue

Anaximander, who Pliny the Elder described as having "first opened the doors of nature" [11] and of whom Rovelli says that "he set in motion the process of rethinking our worldview—a search for knowledge based on the rejection of any obvious-seeming "certainty", which is one of the main roots of scientific thinking" [4], was the originator of the first scientific theory for the origin of life from water developed over several centuries by the Ancient Greeks. Anaxagoras has been called both "perhaps the first empirical astronomer" [13] and "the most brilliant scientist of antiquity" [9], and is credited with being the originator of a further theory of the origin of life, that of panspermia. We should not forget these foundational origin-of-life achievements of the Ancient Greeks from some 2500 years ago.

Acknowledgements In February 2023, Electra Kotopoulou and Pamela Knoll, helped by Marloes Bistervels, organized a workshop in Athens "Self-Organization Reactions on Early Earth: From Pseudofossils to the Origin of Life", held in the building decorated with the fresco shown in Fig. 1. I should like to thank the triumvirate for making me think more about the history of the first ideas on the origin of life. I presented a first version of this paper at that meeting, under the aegis of the COST funded programme on chemobrionics; I acknowledge the contribution of the COST (European Cooperation in Science and Technology) Action CA17120.

Author contributions I, Julyan Cartwright, am the sole author.

Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no conflict of interest.

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