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The Birth of Science in the Pre-Socratic Tradition

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ABSTRACT

This paper is an attempt to identify and analyze a certain number of properties of the pre-Socratic philosophers, which were essential for the birth of the natural sciences in the western civilization which followed. In this sense, the paper investigates a number of the pre-Socratics – in particular, Thales, Anaximander, Anaximenes, and Pythagoras. Nevertheless, the investigation is not undertaken in the usual sense, as it is done in the school literature. The focus of the paper is on the scientific aspect of their theory from the modern perspective. Furthermore, the paper proves that the pre-Socratic theory was not a mere cosmologically-mythological mixture of the ultimate metaphysical speculation, but that it was marked by rationality despite being immersed in a sea of orphic numerological mysticism.

Key words: science, myth, the rational critic, public debate, nature, the Greek miracle

Introduction

In the majority of cases, philosophers perceived science as single and unified. Unity as such has a structure of its own – metaphysical, in

the majority of cases. Various philosophical contexts breed various meanings of the notions of unity and single. Most of the serious questions and investigational problems refer to the issue of unity as being rooted in the philosophy of the pre-Socratics and their Greek cosmogony, as well as in what could be termed as *science*. Pre-Socratic interest in the notions of Single and Multiple that also remained relevant for the philosophy developed later on is particularly interesting. The significance of the relationship between the single and the multiple was interpreted by each and every philosopher in their initial works. The pre-Socratics ended to explain the existence of the world by means of several simple constituents that were perceived as fundamental – for instance, Parmenides' indivisible single, Empedocles' four elements, Heraclitus' dialectical dynamics of the unity of incompatible Empedocles' elements by means of fire, Democritus' atoms or Pythagoras' numbers, as well as Plato's forms and Aristotle's categories. The basic question of the unity of our types of knowledge was explicitly determined as knowledge that undoubtedly is single, pointing out that each of its parts has a separate notion of its own by Plato in his *Sophist*. Namely, language recognizes a multitude of shapes or attributes of knowledge, but has a single substance. In order to be able to comprehend the ancient Greeks' idea of unity, as well as the pre-Socratic one, it is essential to look back on the basic property of their ideas – the tendency to interpret and comprehend nature. Apart from the highly abstract and practically incomprehensible metaphysical contemplations typical of them, relying on the historical data about the pre-Socratics, it can be assumed that they were also characterized by a tendency that was seldom investigated and mentioned – the tendency to investigate and to elegantly and simply interpret nature and the universe. That impulse, moreover, gave birth to science. This paper will elaborate on that process.

The subject of this paper is the science of the Greeks, from its very beginning until the death of Parmenides and Heraclitus. A great number of philosophers argue that science was developed by the ancient Greeks. Nevertheless, a question arises: what is implied by the word science in this case? Each philosopher and each historian offers his own interpretation of science. Can it be that the subjective thesis that the ancient Greeks gave birth to *science* is, in fact, the reason why it was accepted as true? Can it be possible that the civilizations older that Greece (such as Egypt,

Babylon, Mesopotamia, or Assyria) were the ones who originated science?

"However, the question as to whether the Presocratics were also the founders of *science* demands deeper analysis. The history of contemporary science begins with the Renaissance. While Galileo Galilei (1564–1642) was the founder of contemporary experimental science, Francis Bacon (1561–1626), though not himself a scientist, is considered the originator of the new inductive method." (Vamvacas 2001, 20)

The notion of science is of a more recent date, and is not found among the ancient peoples, not even Greeks. The modern meaning of the word may be equal to the ancient *notions of the love of wisdom*, *knowledge* (ἐπιστήμη), *logos*. To translate each of this notions as science would be partly correct and partly incorrect. Despite this, they are useful because they refer to the spiritual disciplines and the areas of spirit that later on formed parts of science. Further problems arise due to the fact that different ancient thinkers offer different relations and interpretations of what we now label as scientific. Various philosophies and theoretical fundamentals provided various guidelines for the investigation and the understanding of nature, given that the natural philosophers were the nearest approximation to the modern concept of a scientist. Modern sciences that are most similar to the ones in which ancient natural philosophers engaged themselves are ontological mathematics, physics, biology and astronomy.

The sources of information about this period are indeed mostly literary or religiously-mythological, whereas the data that provide premises for the conclusions are often rather uneven. The historiographical facts regarding the technology and the interaction between science and technology at that time are particularly poor. The data concerning numerous prominent thinkers (scientists), especially the ones belonging to the earlier Greek history this paper is interested in, is found in the books usually loosely written by the latter authors, and are mostly unclear, inconsistent or biased. In addition to these, certain lengthy medical texts from the 5th and the 4th century are available, as well as the majority of Plato's philosophical dialogues and most of Aristotle's philosophical debates. Regardless of the state of affairs, the intellectual hope to be able to provide a legitimate assessment of science in the ancient Greece remains.

The notion of science is more precisely defined here, due to the needs of this paper. The meaning of the notion relevant for us is the one accepted by the western civilization, and it was formulated by Thales (Allman 1877, 160-175), and the rest of the pre-Socratics. Aristotle begins his *Metaphysics* with the proposition that Thales is the first philosopher who began to search for the natural cause of things (Aristotle, *Met*. I. 3, 983b 20-26). Thales and the rest of the pre-Socratics–Anaximander and Anaximenes, indisputably relied on the previous ideas and beliefs, both the Greek and the non-Greek ones. Nevertheless, their attempts to find the cause of the world in nature mark the definitive separation from the past, which is why it can justly be assumed that they are the first people engaged in science.

The ancient Chinese could also be said to have originated the first science, but this paper will not dwell upon he matter. This issue has been the subject of the book by Needham (Needham 1956).

In order to be able to evaluate Thales' aspect of originality, we need to take into account the achievements of the Middle-Eastern civilization with which this Milesian came across with. We begin with technology. A series of extremely relevant technological breakthroughs took place in Mesopotamia during the 4th and the 3rd millenniums BC, while the similar ones followed in the valley of the river Indus and in China. The history of metallurgy shows that numerous techniques of extracting ores from stone have been mastered. The techniques of melting and forging were already known even before 3000 BC, and around that time the production of copper alloys began. The processes of spinning and weaving also originated around the same time. Ancient Egyptians' skills of textile production can be evaluated from the remains of garments that have been excellently preserved within the pyramids. Ceramics is the third invention that had far-reaching effects on the economy of the first societies. In the beginning, pots were made by hand, and later on by means of pottery and wheel tools. The evolution of agriculture, the cultivation of various types of grain, the development of irrigation systems and the taming of animals, as well as the emergence of the methods of preserving and preparing food were even more relevant for the people and the growth of cities (Neugebauer, 1975).[1]

[1] Otto Neugebauer became the most prominent person who threw light on the pre-Greek peoples and their science and mathematics with this hundred-

Finally, writing is an invention that dates back to the fourth millennium BC. For the majority of inventions it is impossible to ascertain the exact way in which they came to be. It is reasonable to assume that accidents had a major role in the processes. In the case of ceramics, for instance, it may be possible that clay was accidentally forgotten in fire and that it gained some new and better qualities. Nevertheless, the creativity of the ancient people cannot be disregarded. The case of penicillin is useful for proving this point. People would unquestionably wonder how to prevent the appearance of mold on the containers in which lemon is kept if it had not been for Alexander Fleming and his discovery of penicillin! The development of metallurgy and textile production was a series of experiments followed by dozens of mistakes. The predecessors of the scientists restlessly experimented in the general, non-technical sense of that word – in other words, their experiments did not aim at testing theories, but at enhancing the final products of their labour, so as to obtain the best alloy possible.

Claude Lévi-Strauss, a great French anthropologist, pointed out the complexity and the accuracy of numerous classifications which can be termed scientific and which he found in the primitive or archaic societies. A great number of natural, animal or plant classifications from that time – although not being able to be labelled scientific in the modern, methodological sense, are astonishing due to the obvious skilled perception typical of them.

Thales' love of natural causalities

Despite the previously mentioned contributions of the eastern peoples to the fields of medicine, mathematics and astronomy, it can be assumed that Thales was the first scientific philosopher. An investigation of the meaning and the validity of this claim issues. Naturally, this Milesian thinker and scientist is not expected to provide an entirely articulate, systematic investigation. His research was rather limited in scope. Thales was utterly unaware of the notion of the scientific method we now know. The science of that time – if it can even be termed science – cannot be contemplated without the use of the metaphysical notions

and-five-thousand long book It represents the best model for all those dabbling in mathematical and astronomical writings.

such as archē (ἀρχή) or substance (οὐσία) – the ones that are not scientifically defined to this day. Nevertheless, two major characteristics differentiate the Milesian philosopher from his predecessors – both the Greek and the non-Greek ones. *The formulation of nature* is the first one, *the common resorting to the rational public critical debate* the second one.

The origination of nature is reflected in pointing out the difference between natural and supernatural, or, in other words, the realization that the natural phenomena are not mere effects of accidental or arbitrary impacts, but rather normal events that stem from causal relationships. Thales' arguments, and even Plato's, are reminiscent of the earlier myths. What is implied by this is that they are not different from the mythological conclusions in the sense that *the supernatural forces are practically not involved.* The original philosophers were not atheists, given that the gods are very present in Thales' ideas. It is relevant to point out that whereas the idea of the divine often appears in his cosmology, the notion of supernatural never forms part of his arguments.

For example, the first theory on earthquakes is ascribed to Thales. It is known that he conceived of the Earth as a unity held by water, and that the earthquakes were a result of a wave of this omnipotent liquid. The conception of the Earth floating on the water is also present in certain Babylonian and Egyptian myths (Neugebauer 1975, 1077-1081), whereas the common Greek belief claims that the one responsible for the earthquakes is Poseidon, the god of sea. However, Thales' theory on the earthquakes was the first one in history that provided a naturalistic explanation, rather than mentioning Poseidon or any other deity! While Homer and Hesiod explain lightning as Zeus' or Poseidon's wrath, Thales' again excludes all references to the will of gods, their love, hate, passion or any other human motive, thus leaving gods to religion, art and philosophy, until the time of Aristotle. In addition to this, Homer describes a particular earthquake or a particular lightning, whereas Thales focuses on earthquakes and thunders in general, rather than on the individual instances of these phenomena. Thales' research was directed towards the classes of natural phenomena, which led way to the formulation of the scientific property also present in its modern formulation – the tendency to investigate the universal, *unified* and essential reality, instead of the actual, pluralistic and accidental phenomena.

Another historical phenomenon that proved to be a suitable basis for the formulation of science is the development and the cultivation of debates or free dialogues. Socrates and the art of debate and the culture of dialogues are not a single and the isolated instance, but the crown of a long and rich tradition that has been developing long before him – according to Plato's dialogues. Verified evidence show that the ancient Greek pre-Socratic philosophers were aware of one another, as well as that they criticized each other. Proof is often found among the philosophers' writings. Parmenides, Empedocles and Anaxagoras' successors adopted the following principle: *none of the predecessor's insights are to be used without being critically explored in the sense of literal repetition.* Prior to this, Heraclites claimed this was also true of his predecessors and contemporaries – especially in his fragment 40, arguing that lots of learning does not lead to wisdom, since, were it true, Hesiod and Pythagoras, as well as Xenophanes and Hecataeus would be wise (Marković 1983, 43-54).

The majority of historiographical evidence available are related to the time of Socrates and the one after him, but, by reason of logic, it can be assumed that the tradition of creative criticism and the culture of dialogue can be traced back to Thales. This is cleared out by the nature of the rival theories that gave rise to the specific themes such as the question of why the Earth is still, in addition to the one related to the origin of things in general. An interesting issue raised by the contemplations of the roots of the culture of dialogue and debate is the one asking how the circumstances in which Thales created his ideas positively influenced the appearance of science. A comparison of Thales and his even earlier predecessors follows. The topics they elaborated on were also investigated in the ancient Middle East or in the early Greek mythological period, where they also included the interest in the origination of the world, in the manner in which the Sun revolves around the Earth, or in the way the sky holds up, but each of the myths that deal with these issues *is independent* from the rest of them (Couprie 2011, 63-67). The Egyptians, for instance, offered a number of different beliefs about the thing that keeps the sky from falling (Neugebauer 1975, 563-565). Of the ideas states that the Earth is placed on columns, the other one that the sky is being held by God, the third one that it is supported by a cow or a goddess whose hands and feet touch the Earth. Nevertheless, all of these explanations

are independent, abstract and stand in no critical relationship to one another, but are rather separate and isolated in the world of beliefs and thoughts.

The above mentioned mythical presuppositions do not represent competition to the other myths – none of the myths that aim to explain a certain natural phenomenon is more or less accurate, or has a better or worse theoretical foundation. Nevertheless, a closer look at the early Greek philosophers reveals a basic difference between the logics of the myths. Many of them investigate the same problems and the same natural phenomena, but it is assumed that different theories and explanations they offer are directly mutually combined. The theoretical need to find the best explanation and the weak spot in the theories of the opponents grows. This is perceived as one of the paramount causes of the birth of science. The pre-Socratics, on the other hand, were still rather dogmatic and suggested their theories were not temporary but definitive solutions to the problems. Nevertheless, they often displayed their awareness of the necessity to investigate and evaluate theories in the context of the basics of nature – and this principle presumably is a mandatory prerequisite for the advancement of philosophy and science.

Miletus, the place where the original science was born

Contemplation of the starting points of science and philosophy from the modern perspective does not offer a decisive insight into the reasons why the rise of the intellectual qualities happened precisely at that time. It is highly unlikely that the precise and comprehensive answer to that question will ever be given. Relying on pure logic, we can assume that the answer lies in the geniality of certain philosophers. German Hellenist Werner Jaeger came up with a compound noun to explain this wondrous events that have never been repeated again – the Greek miracle. Nevertheless, he does not provide a single argument or explanation of how and why this happened. This is not an explanation, but rather an invitation to provide one. Not even the economic suggestion would not suffice for those with the metaphysical fondness for reality and history.

Miletus was a rich town, until it was destroyed by the Persians in 494 BC. Its wealth stems from its wool industry and partly from its trade. That Miletus was one of the first colonizers is a well-known fact.

This could have been a possible, but not a sufficient reason for the fact that the first philosophers appeared there. The material prosperity of Miletus at that time was not significantly larger than the one of the other Greek cities, nor the ones outside Greece. It is also possible that not all of the historiographical information about Miletus are known to us (Henry 1995). Even though this paper will not deal with this issue any further, it will offer a list of certain aspects of it.

The Milesian philosophers did not formulate a completely articulate system of knowledge. Had they done it, it would indeed have been a miracle. Their breakthrough is reflected in the fact that they rejected supernatural explanations of the natural phenomena and the establishment of the practice of critique and debate. In order to better comprehend the background of this development, it is necessary to look into the economic factors and the Greece's political context of the time. It is there where the contrast between Greece and the prominent Middle East civilizations is most obvious. Despite the fact that the historians tend to convince us that Greece was more peaceful and stable that Lydia, Babylon and Egypt, that is far from accurate. On the contrary, the period was marked by great political restlessness and turmoil found across the Hellenic world (Plutarch 1960). As was the case of the rest of the Greek cities, Miles faced political quarrels and tyrants. The institution of the city-state we now know as polis underwent structural changes in the 7th and 6th centuries. The development of a new political awareness is reflected in the spreading of the forms of constitution – ranging from tyranny to oligarchy to, ultimately, democracy, according to Plato's Republic. The citizens of the states like Athens, Corinth, or Miles not only took part in ruling their countries, but they also participated in the active debate about the best form of ruling (Joseph 1981(1948)).

The above stated insights are not sufficient to account for the fact that among all the Hellenic cities, Miles was the one that gave birth to the first philosophers and some of the best scientists in the world history. For the best, or for the worst, the present condition of our knowledge does not provide a clear answer to that question. The economic and the political situation of Miles does not lead the discussion any further, since it was more or less similar to the one in the other cities. Nevertheless, the freedom of questioning and criticizing one another allowed to the phi-

losophers of that time can be compared to the spiritual conditions found 2500 years later. What is more, it can provide a suitable model.

It is known that Thales' ingenuity and inventions were not limited to speculation. A couple of his anecdotes illustrate his engagement in matters of business and politics: Herodotus, for instance, explains that Thales advised his countrymen on how to establish a common political council with the aim of joining their interests. Both Thales and Solon were regular members of the Seven Sages. Solon himself was mostly familiar for his far-reaching constitutional reforms that took place in Athens in 594 BC. He left behind certain poems which illustrate his objectives and his guiding principles, and additionally point to the fact that he embraced personal responsibility for his actions. The crucial point of his reform was the publication of the laws that were available for all the Athenians (Irwin 2005, 99-101).

Despite the fact that Thales and Solon are utterly different in terms of spirit, interests, spheres of action, the philosopher and the legislator have at least two things in common. Firstly, they both rejected every supernatural authority, and secondly, they embraced the principles of free debate and public access to information of public importance – unlike certain modern politicians. The key purpose was a new critical spirit of men's relation towards nature and society.

Pre-Socratics, being in close proximity to myths and mythological world view, paid a lot of attention to the rare or frightening natural phenomena. Their aim that we now term scientific was to provide naturalistic explanations of the phenomena which were perceived as controlled by the gods. Zeus was responsible of thunders, Poseidon was in charge of earthquakes, Atlas held the Earth on his shoulders. Natural explanations of the pre-Socratics are a recognizable and a special success of theirs, which forever superseded the belief that the natural events were products of the supernatural forces. Thales hence explained that earthquakes were the results of the pressure of the water the Earth floats in. Similarly to this, Socrates' teacher, Anaximander, noticed that thunder is provoked by wind and that lightning is produced when clouds are split in half. The relevance of these apparently naïve explanations does not lay in their professionalism or sophistication – as is the case with the modern scientific explanations, but rather in the fact that the free will of

the anthropomorphic gods and creatures was from that moment on forever excluded from science.

Anaximander's conception of nature

An elaboration on Anaximander follows. According to Anaximander: "the original state of affairs consisted of some everlasting stuff, which he elsewhere calls "the boundless." From this primordial stuff some seedlike substance was, as it were, secreted, which gave rise to differentiated things such as hot and cold. From this arose a mass having an earthy nucleus surrounded by a layer of air, surrounded by a shell of fire. The mass burst, producing concentric rings of fire enclosed in air, surrounding a cylindrical earth. The rings are invisible because of the air surrounding them, but a hole allows the fire inside to be seen. The outer ring is that of the sun, the middle that of the moon, and the inner ring, or, presumably, set of rings are those of the stars" (Graham, 2006). At first, he intended to represent the celestial bodies as fire balls. Regardless of the importance of this theory, it is the first attempt that can legitimately be considered an instance of a mechanical model of the celestial bodies in the Hellenic astronomy. Neither did Anaximander nor any other Greek theoretician develop a systematic and comprehensive theory of astronomy (Khan, 1960). He was the first Greek who used a sun clock, already well-known in the Middle East by that time, as was able to determine the dates of the two solstices – the shortest and the longest day of the year, and the two equinoxes:

"Presocratics seem to have considered necessary; he made it circular because the horizon does seem to encircle us, as indeed., mythological tradition, with its surrounding Okeanos, had implied he gave it depth because it seemed very solid below, as the tradition also testified (Tartaros is far below in Homer and Hesiod); and he made it one third as deep as it was wide to fit in with the ratio of the heavenly bodies, which was not opposed to observation and which embodied a traditional symmetry between sky, earth, and the underparts of earth. Thus Anaximander's arrangement of the cosmos was related to observation both directly and as expressed in mythical or traditional form."[2]

[2] Kirk, 1960.

He elaborated on the nature of the heavens and the origination of the Earth and the human kind. Noticing that the Earth is rounded, he came to believe that is had the shape of a cylinder cut by an axis laying in the west-east direction. He believed that the Earth was floating in space, which was a new theory. He was aware of the idea of balance in the area of the physical and that of moderation and justice in the ethical area.

These examples show that, at a very early stage, the Hellenic philosophers began to contemplate the problems that form the basics of physics, astronomy, human kind and the development of men from nature to culture – which are all parts of certain modern sciences.

The three main theories ascribed to the pre-Socratics are their general cosmological doctrines interpreted by Aristotle, who connected them to *the material cause* of things in his *Metaphysics*. Namely, Thales was to ascertain it was water, Anaximander that in was *apeiron* and Anaximenes that it was *air*. All this indicates the fact that the first Greek philosophers were aware of the fact that the cause had to be unified, or unitary, so as to account for the recreation of the entire reality. This metaphysical and scientific intuition that something needs to be unified and coherent has been transmitted into the explicit science.

In his *Metaphysics,* Aristotle argued that the majority of the first philosophers believed that the principles of the natural matter are the sole principles of all things. What forms all things, what formed them at first and what they turn into once their end comes – the substance that always exists in the same shape and only changes its properties, in fact is the unitary element and the principle of all things (Aristotle, *Met*. I.7, 988a 20-25).

Notions translated as *matter*, *substance*, *attribute*, and *element* were first introduced into philosophy in the 4th century, and it is inconceivable that they could have been used by the pre-Socratics. Poet Hesiodus made it clear in his *Theogonia* that *chaos* was what existed before all else. He continued to explain that the gods were the creators and even connected them all into a large family tree (Clay, 2009). It may be true that Thales wondered about the origin of things in the sense of what came first, even though the answer he provided was basically different from the Hesiodus', since he mentioned no mythological reason, but rather a natural, common one – water. One can legitimately wonder: did Thales

believe that the chair he sat on and the bread he ate were also made of water?

Anaximander was also a Milesian philosopher and a philosopher who initiated the philosophy of mind. He suggested that the original element was not a specific substance, but something unspecified, which he termed *apeiron*. Anaximander may have noticed a problem present in Thales' vision. Namely, if water is the original element, can fire, its opposite, ever exist, given that each opposite destroys the other? If Anaximander had really based his theory on this presupposition, it would represent a suitable illustration of the above stated insights – in other words, the thesis that theories stem from the realization of the possible objections to and problems of the predecessors' theories (Khan, 1960).

Anaximenes – the first man who realized air exists

The third Milesian philosopher, a pre-Socratic and a Thales' successor was Anaximenes (Anderson, 2000), who parted ways with the mythical even further, and entered the realm of the scientific, given that he offered a definitive representation of the changes *air* goes through in order for earth or stone to originate. The available sources do not show how Thales explained the issue. It is impossible to ascertain whether it is simply due to the lack of available information, or because Thales never contemplated the issue. Despite Aristotle's testimonies, even if Thales wondered and answered the question of what came first, the theory on how the basic element is retained in the objects we see around us was probably formulated by the pre-Socratics some time later.

Anaximenes also did not mind the fact that the lacked a technical dictionary that refers to the qualitative modifications of the basic elements or substrates – which is how philosophers prefer to call them. It did not stop him from explicitly proposing the idea of the change that affects the basic element. According to him, that element was air, which may, at first sight, look like a step back from the tangible ones – Thales's water and Anaximander's numerous metaphysical postulates. What matters is that Anaximenes combined theories. Rain is an illustration of how condensation forms water, whereas cold turns water into solid ice and ice into air. For instance, air is formed by the separation of water while it evaporates or is being cooked. These simple and obvious facts provide basics for Anaximenes' scientific generalization that all things

stem from a single basic element undergoing a single two-way process of condensation. Unlike Anaximander's metaphysically brilliant, but random conception of the world that grows out of undifferentiated apeiron, Anaximenes' theory referred to the processes that can be seen in natural and visible phenomena;

„Anaximenes believed everything to be natural and explained phenomena citing only natural entities is similar to that for Anaximander and Thales. There is no extended world for Anaximenes. Anaximenes believed that everything came from and could be destroyed back into a single, natural substance. Anaximenes believed this to be air." (Gregory 2013, 57)

Anaximenes' theory of condensation offers a more clear view of the changes that influence the basic element than Anaximander's idea. As is usual in the history of science, the actual theories are later unjustly represented as the childhood of science, which allowed for the appearance of Aristotle, despite the fact that the Milesians were far more advanced this great philosopher. However, the figure of Aristotle does not dispute the significance of their achievements and the progress they made in the process of understanding the problem. By casting off the supernatural causality, they introduced the natural explanations, or, in other words, were the first men that initiated the scientific conception of the world.

Pythagoras and the inherent ability to mix the mystical and the natural for the sake of science

The speculative thinkers of the 6th and the 5th BC are known as the first philosophers. However, the fact that the term *philosopher* is applied to all these people should not blur the relevant distinctions that existed between them, since their goals, interests and their social roles were severely different. There are a couple of striking contrasts between the Milesians and the so-called Pythagoreans, which were, themselves, different amongst each other.

Data on Pythagoras are rather scarce. He is believed to have been born on the island of Samos, and that he eventually fled to Croton, so as to escape Polycrates' tyranny. The Pythagoreans referred to themselves as deities, and even described themselves in terms of properties usually ascribed to the gods. Pythagoras mastered the art of living – according to another Pythagorean, Plato, who wrote about it in his *Republic*. Accord-

ing to him, Pythagoras was particularly loved because he taught to his followers a way of life today known as Pythagorean, and that made them believe they were different from the rest of people owing to it (Plato, *The Republic* X 600b). The earlier Pythagoreans were not much interested in the investigation of nature. The formed a group similar to the modern sects, whose members were closely tied - in particular, with respect to their religious beliefs and the practices of mysticism. They adopted their creed from Pythagoras' eastern travels, and it was the belief in immortality and the transmigration of souls. Ritual abstinences were also peculiar to them – for instance, the ones related to certain types of food such as beans, since they believed that the germs contained in beans were actually mediums that enabled the moving of soul from one world into another. The fact that they had enormous political power in certain city-states in *Magna Graecia* is almost surprising[3]. Nevertheless, it was simply one of the modalities of the Pythagoreans.

Aristotle claimed that the Pythagoreans were the first ones who dealt with mathematics and who believed that the mathematical principles were the core of all things. However, numbers are the first of these principles, and the Pythagoreans notices a greater number of similarities between them and the existing things – much more than the number of similarities between those things and fire, earth and water. Due to this, they argued that all those things were formed and modeled in relationship to numbers, whereas the heavens represented a music scale, a sphere and a number (Aristotle, *Met.* A.I, 985b 26, 986a 5-15). [1] Aristotle hence believed that the Pythagoreans found the roots of everything in numbers. Whereas the Milesians chose material substances as the basic elements, the Pythagoreans focused their attention on the formal aspects of phenomena. Regardless of whether they were the first or the second ones who recognized the numerical relationship of the musical harmonies, this definitely accounted for one of the key examples that illustrate the role of number. The intervals of an octave – a fifth or a fourth, for example, may express the notions of simple numerical relations – 1:2, 2:3 and 3:4. What was astonishing in this illustration is the fact that the phe-

[3] Magna Graecia or the Great Greece (Greek Μεγάλη Ἑλλάς) is a notion applied to what is now located in the south of Italy, or, to be more precise, the area that was colonized and controlled by the Greeks since the end of the 8th century BC (Casadio – Johnston, 2009, 61-73).

nomena that had no apparent connection to numbers had a structure that could be mathematically expressed. For the Pythagoreans, it seemed logical that if this can be applied to music, it could also be referred to other natural instances, given that the mathematical relationships are discovered in the structure of the world. The theory that mathematics lies in the core of the world or, in other words, that a demiurge has created the world according to the mathematical principles is one of the most prominent theories in history that accounts for the formulation and the creation of science and scientific opinion in general.

The Pythagoreans were the first theoreticians who attempted to rationally determine the knowledge of the world as a knowledge of the nature of the quantitative and the mathematical. This indicates that their breakthrough is of paramount importance for science. They did not only discover that the formal structure of the world can be expressed in numbers, but also that things consisted of numbers. Many of them assume numbers are contained in things, whereas the numbers themselves are perceived as actual material objects. This marks the beginning of ontological mathematics.

Many of the alleged similarities the Pythagoreans claimed to have found between numbers and things were, in fact, quite fantastic and arbitrary. For instance, they equated legislature and number 4, or the first square number, or marriage with number 5 that represented the unity of male number 3 and female number 2.

Pythagoras' search for the numerical indicators in the world unexpectedly proved to be quite fertile for the analysis of the musical harmonies and in astronomy, which, nevertheless, resulted in the numerical mysticism (Casadio – Johnston 2009, 131-139). In this respect, the Pythagoreans were largely influenced by the religious and the ethical motives. They believed that the heavens were a music scale and a number. Moreover, relying on the doctrine of the harmony of spheres, the movements of the celestial bodies are not soundless, but we are unable to hear them because we are used to these sounds since the day we are born! Furthermore, soul is also pictured as a harmony, and its blissfulness depended on whether is well-grounded and ordered like the universe itself.

Pythagoras' discovery of the relationship of the musical harmonies was a subject of many antic legends, some of which attempted to de-

scribe the way he reached his conclusion – in a mystical way or by means of a simple experiment. Plato points out certain early experiments in the area of acoustics, which further add to the credibility of his testimony, given that he himself did not support this way of solving problems. In his *Republic*, through his comments on Socrates he speaks of the ones who measured harmonies and sounds they heard, as opposed to those who tied wires to nails and searched for numbers and relationships between the spheres in the harmonies they heard. Nevertheless, this demonstrated that the Pythagoreans understood the value of experimenting and that they experimented – in acoustics, for instance (Plato, *The Republic* VIII 546c). This poses the question of the significance of the discoveries obtained in such manner and whether they aimed at mystically and intuitively expanding the theory of numbers onto the entire reality and the universe.

However, these mystical doctrines did not prevent, but they rather encouraged the Pythagoreans to come up with the scientific speculations about the relations between the celestial bodies. A number of different theories are ascribed to the Pythagoreans in general or to the precise groups and individuals amongst them. For instance, in one of his doctrines, Pythagoras speaks in favour of one of the early Pythagorean traditions that states the Earth is in the center of the universe and that it contains a fire core. Post-Aristotelian sources ascribe yet another theory to Pythagoras. The central fire is not within the Earth, but is a separate body, whereas the Earth itself, as well as the other celestial bodies, revolve around it. This system, therefore, is neither geocentric, nor heliocentric. The center is an invisible fire body, but what further complicates the theory is the introduction of another invisible object – the well-known counter-Earth, which surrounds the central fire beneath it. Therefore, the center is occupied by the central fire, embraced by the counter-Earth, surrounded by the Earth itself, out of which the Moon, the Sun and the planets are located. The main evidence in favour of this claim are to be found in the two excerpts from Aristotle's writing that criticize the basics of its foundations. The most prominent philosopher asserts that the Pythagoreans came up with another Earth, opposite to ours and labeled counter-Earth, without attempting to come up with evidence or explanations, but rather trying to erase the contradiction that arise in the

process by means of violence and offering objective claims. (Aristotle, *Met*. I.5, 985b 23 - 986a 22) [2]

This Aristotle's critique is not where his disagreement with the Pythagoreans ends. Moreover, in his *Metaphysics* he continues to explain that the Pythagoreans placed all of the properties of their numbers and the entire construct of heavens into a scheme of theirs; moreover, they readily filled all of the blanks so as to continuously make their unity coherent. For instance, taking into account the claim that number 10 was considered perfect and that in contained the entire nature of the numbers, the Pythagoreans argued that there are 10 bodies that moved through the heavens; however, since there were only nine visible ones, they simply came up with the tenth one – the counter-Earth. (Aristoteles, *Met*. I.5, 986a 5-30)

Aristotle dismissed the theory of the counter Earth, arguing that it was a part of the miraculous mysticism and suggesting that something is missing from the story since the theory came across serious difficulties. Nevertheless, the details of a large number of Pythagorean theories, as was the case with others in the pre-Socratic astronomy, remain unclear, and to this day, it is impossible to ascertain whether Aristotle was right or wrong, given that, in the scientific sense, it is impossible to derive precise mathematical evidence and consecutive logical arguments.

The most interesting property of the system, without a doubt, is the fact that the Pythagoreans did not place the Earth in the center of the universe. Furthermore, this was a consequence of the symbolic reasons, rather than the scientific ones provided by Copernicus 2000 years later. Being a geocentric, Aristotle almost angrily argued that the Pythagoreans did not consider the Earth was valuable enough to occupy the most relevant position in the universe.

The history of mathematics in the first pre-Platonic period remains utterly unclear. Reliable first-hand evidence are poor, whereas the speculations about that time are abundant. Euclid's elements were, without a doubt, based on some earlier works unknown to us. The Pythagoreans were mostly engaged in the certain aspects of the number theory by the middle of the 5th century BC. The classification of the numbers from the time is, to say the least, odd – as is, for example, the establishing of connections between certain numbers and various geometrical bodies. That's how 4 and 9 came to be square numbers, whereas

6 and 12 were labeled oblong! The early mathematicians from the 5th century BC certainly were familiar with certain simple geometrical theorems, including the one named after Pythagoras himself, which states that the square of the hypotenuse is equal to the sum of the squares of the other two sides. Truth be told, the theorem in question had already been known to the Babylonians for a long time. Therefore, the scientific contribution of the Greeks was reflected in their proving it true, their interpretation of the evidence, and in their development of the methods of mathematical demonstration. This was a breakthrough that happened in the 5th century or in the beginning of the 4th century BC, and is unquestionably connected to the other mathematicians that were not Pythagoreans.

Conclusion

What was the key reason why the pre-Socratics were so relevant for the ancient Greeks' origination of science? Two of their inventions mark the beginning of science. The first one is the evidence of their empirical research in the area of acoustics, including *the use of simple experiments* and the second one is *the development of the deductive scientific and mathematical methods.*

Owing to their versatility, the pre-Socratics superseded all of the wise men that were prominent prior to their appearance. Hydrotechnicians, merchants, politicians, astronomers, mathematicians and finally philosophers were all brilliant practitioners. Their wise contemplations raised them above the sphere of common use or mythological reasoning. In that manner, they became the founders of both science and philosophy in general. Casting aside all the mythological and the theological factors, and introducing natural causality and consequences, they were the first ones they made a rational attempt to explain nature (φύσις) in a natural manner. Through the perception of certain objects, phenomena and processes in nature – both organic and non-organic one, they discovered changes, and then something unchangeable and unique in those transformations, something that is the core of everything and the end of everything. Matter was perceived as the basis of all things, and something that can be empirically checked. These principles represented not only the general foundation of life, but also the ultimate cosmic factors. We are now left with nothing but the opportunity to enjoy the intellectu-

al pleasure the study of the pre-Socratics offers. Also, it is impossible not to philosophically marvel at the Greek miracle.

„The questions which the Pre-Socratics tried to answer were primarily cosmological questions, but they also dealt with questions of the theory of knowledge. It is my belief that philosophy must return to cosmology and to a simple theory of knowledge. There is at least one philosophical problem in which all thinking men are interested: the problem of understanding the world in which we live, including ourselves, who are part of that world, and our knowledge of it. All science is cosmology, I believe, and for me the interest of philosophy as well as of science lies solely in their bold attempt to add to our knowledge of the world, and to the theory of our knowledge of the world.“[4]

Notes

[1] Aristotle's *Metaphysics* translated by Tomislav Ladan in the free interpretation of the author of the text.

[2] One ought to be cautious when dealing with Aristotle's critiques. For instance, when suggesting that the majority of the pre-Socratics investigated the same issue, he mentions the material cause of things which is a concept of his own, already formed in his *Metaphysics* – rather than an idea of his predecessors.

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[4] Popper, 1958.

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