Philosophical Aspects of the History of Science

Andrej Démuth

Edition Cognitive Studies

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An Apology instead of an Introduction

Starting a textbook with an apology is a rather less common practice, however, this text demands it due to a plenty of reasons, following the example of Ken Binmore (1994, 1998). The intention of the presented text is neither to provide a complex view of history and development of science nor to focus on its most significant milestones. The first apology is directed to those who expect that this book would provide mainly historical data and evaluation of historical connections of scientific discoveries and inventions. Owing to an extent and subjective relevance of individual events, I believe, it is quite impossible to fulfil such expectations since especially encyclopaedias aspire to this function.

The second apology goes to those who expect a textbook in a form of enumeration and detailed descriptions of individual events or hope to acquire generally accepted historical concepts and terms. Diversity and a broad spectrum of scientific disciplines (including natural, social and spiritual sciences, nomothetic and idiographic methods, empirical, exact even also soft approaches) and nature of history itself cause that a homogenous concept of science and mainly of history as such does not exist among historians and science theoreticians, and that is why we do not want to provide a reader with a certain conception of history of science, instead, we would like to present various viewpoints on propositions of individual authors. The presented text focuses rather on enabling access to philosophical aspects and ideological residuals found in several scientific approaches and issues. It means, analyses of conceptual schemes but also of phenomena present in their implicitly perceived background are to be dealt with. It is essays on science, its roots, and essence but also on relations of science and philosophy and also on heritage which philosophers left in science that I thematize. And also a form of the presented research corresponds thereto.

The text *is not* a classical textbook — an exposition, it is rather a philosophical essay (in the original sense of this word: an examination, (re)consideration, experiment). It is an attempt to ponder on a nature of sciences, methods and procedures, evidences and also on axioms and explanatory bases, but at the same time it represents an attempt to assess them. From this viewpoint, it rather complicates issues than provides answers to them and that is what the author's intention aspires to: to induce students not to take things for granted and to try to view the world differently from the way they perceived it before. A vision of the world, clarity, looking at and thematizing of an issue which represents a matter of course (and thus which is frequently implicit and beyond doubt), noticing of an issue scientists and philosophers thought and did not thought about, but also why they believed in what they believed that is what represents the main object of the presented research. An attempt to show a picture of the world through the eyes of science within a certain paradigm represents the primary objective of the research. At first, it may seem easy. Of course what is easier than to view the world, for instance, from the Aristotle's viewpoint. However, appearances are often deceptive. To see, for instance, what Aristotle saw means to forget what we know about the world, to leave behind what we believe in and to try to see what Aristotle might have seen and believed in. Only then we will comprehend meaning of his sentences and convictions and only then we will understand why he asserted what he asserted. It might lead us to more profound comprehension of our own scientific concepts.

And it is in this sense that the presented text *represents* a textbook. It should try to teach how to comprehend explanatory bases and limits of philosophical and scientific knowledge but also to

view things creatively, in other than a traditional way. Its task is to make bases complicated and surmise boundaries, and also to find creatively inspirations and new possible outcomes.

I assume that a problem of history lies in the question of its uncovering and making available. How do we know what our forefathers believed in and how exactly they comprehended it? And how do we know what led them to their discoveries and inventions? Can we get to know the past from the present consequences with certainty? (a shape of ice from a melted pool — Taleb, 2011, 212 — 213). Uncovering of history requires reconstruction (arising from a detailed analysis of texts and preserved materials) as well as construction of possible causes through a though experiment. We will rely on both of these elements and we presume that a reader will also go through recommended texts listed at the end of each chapter. Their task is to broaden, clarify the discussed topics in more details or some other way. A series *The Cambridge History of Science* or magazines focusing on history of science, for instance, *History of Science* published by History Publications Ltd. or *The British Journal for the History of Science* published by the University College London represent good examples of this approach.

A legacy of three thinkers dealing with history of science and scientific thinking working in Czech and Slovak language backgrounds represents an unconcealed inspiration of the selected approach. Ladislav Sabela as my teacher is the first one of them. He introduced me to an issue of science concepts and an influence of his propositions and lectures cannot be denied in this work. Petr Vopěnka, a mathematician and science theoretician, attempting to renovate science on the basis of Husserlian phenomenology mainly through his work "*Úhelný kámen evropské moci a vzdělanosti*" portraying history of European science originally and provocatively via history of mathematics and its use for materialised objects — physics, represents the second thinker. And the third one is Ladislav Kvasz, a science historian at present also drawing ideas mainly from Husserl (however, this time predominantly from his

Crisis of European Sciences and Transcendental Phenomenology), who perceives a development of history primarily as a process of modification and formation of a language of science (especially in modern physics). And it is the vision of the world and its interpretation or mediation through a language that represents core of a philosophical approach towards science which we would like to thematise. That is why the presented text predominantly analyses philosophical aspects of history of science and along with a history line tries to thematise the chief methods, concepts and conceptions of a scientific research, as well. Therefore, an introduction of each chapter provides key concepts and terms subsequently clarified in a given chapter. And thus it focuses also on research of diverse conceptions of science and a philosophy of science itself.

Limited extent of the text did not allow the author to deal with the issues more profoundly, it even caused that many problems are described only in very incomplete and thick contours. Broadness of argumentation methods and lines can cause certain distortion and simplification of a structurally difficult object with various details. Therefore, a reader should view this text only as a sketch or provocation to their own future research. The recommended texts listed after each chapter providing references to other issues or more profound study of a problem a given chapter discusses should serve the same purpose.

In Trnava, July 31, 2012 A. D.

1. Myth as a Form of Proto–scientific Knowledge

Key words: *methodology, myth, explanation, heuristics, panoramicness*

If we want to comprehend science correctly, its adequate differentiation and determination against other historical, cultural and social human activities represent one of the chief problems of its understanding. A scientific approach to the world has plenty of particularities which separate it from other research spheres and these are historically, methodologically and culturally conditioned. However, at the same there are many aspects connecting science with religion, philosophy, or myth. Therefore, in the first chapter we will try to focus on links existing among science, philosophy and myth but also to point out epistemological, ontological and methodological relations which can be found in both of them.

1.1 Relation of Philosophy, Myth, and Science

A classical idea about science development claims that a major part of sciences originated by means of their gradual detachment from philosophy. According to this concept, philosophy embodies a mother of sciences — a fount of individual issues (Grant, 2010, 257). Its task was (or is) to formulate an issue as clearly as possible and to look for an approach *(methodos)* securing the most successful solution of the issue possible. When the issue is sufficiently formulated, subsequently, the best approach is considered and its research is taken over by a specialised discipline — science which creates an adequate research method. On the basis of this theory, individual sciences successively detached and formed from philosophy and a process of their further specialisation has been continuing until today. Some sciences develop and perfect their specialisation, others remain on the edge and as time moves on, they leave an area of what is considered scientific (e.g. alchemy versus chemistry). Therefore, philosophy deals with issues other sciences have not yet successfully and individually formulated or found a specific approach towards them, or problems representing scientifically uninteresting (or meaningless) matter. Thus, it is especially a formulation of given issues and a method which can be used to approach the issue that differentiates science from philosophy (Rosenberg, 2000, 2). It similarly concerns also relation of philosophy and myth which the philosophy draws on.

Textbooks of history of philosophy teach us that determination of exact historical and geographical circumstances of origin of philosophy or science is not quite possible. One of the main reasons is the absence of preserved paper or other types of documents, but also the fact that specific philosophical or scientific opinions frequently overlap and are related to religious and mythical explanations of the world they often derive from. That is why drawing of attention to dissimilarities of science, myth and philosophy and also to their common outcomes seems more feasible than determination of historical milestones of science.

1.2 Functional Frameworks of a Myth

Lévi–Strauss's analysis of myth published within his *Structural Anthropology* represents suitable means for proving of common roots of all three approaches to the world. Claude Lévi–Strauss points out that a traditional structure of myth is not only a random mythical and poetical narrative; it rather fulfils mainly metaphysical, cultural, economic and social function. On an example

of the myth of Asdiwal, it can be observed that myths similarly to fairytales offer several significant information frameworks. Besides their attempt to account existence of the world and organisation of individual phenomena within it, a provision of various models of successful integration of a human being with the world plays a significant part in these stories. One of the levels a myth offers is a provision of a symbolic picture of the world which we live in. Thus a myth can contain *geographical and topological* data creating a map of a setting in which it is situated. Its details and exactness depend on significance of message it conveys as well as on the importance of geographical framework for other information in the story. Similarly to a standard world map, the mythical map also contains symbolic cartographic data. The mythical topology is often connected with ethical and economic level of explanation.

We comprehend a concept of the *economic level* as a technological and economic framework of rules which a myth provides. Levi–Strauss pointed out to the presence of technological subsistence practice informing myth users about suitable form, time and place for hunt, processing of food, successful technologies and subsistence strategies, etc. Certainly, not every myth necessarily focuses on this aspect of life, although in principle we can say that a myth and mythology in which it is situated inspire to apply just those technologies and practices which should lead us to successful integration with the world and community or even to their remedy (Honko 1984, 49).

A social framework represents the most frequent level of a mythical narrative. It clarifies hierarchization and relations in a society but also depicts correct behavioural patterns. The children learn already in fairytales that good triumphs over evil and evil is punished. At the same time they learn what is good and what is expected from them. The mythical narrative fulfils axiological and axiogonical task not only in an ordinary life but also in specific life situations — in the given myth, it is a preference of matrilineal and patrilocal marriage (Levi–Strauss, 2000, 167 — 169). Also Spinosa (Spinoza, 1991, 116) like Lévi–Strauss sees primacy of a function of a religious or mythical narrative which forms a society. A range of details within rules can vary (from less to more demanding practice of a social and personal life) to such an extent that in Torah, Talmud and especially in Mishna similarly as in principles of other religions we can find detailed rules describing rituals for God, community and even marriage but also details connected with food preparation and consumption.

The social framework of a myth is connected with *a metaphysical and religious framework*. The myth not only provides a pattern of successful behaviour (Eliade, 1964, 8), it mainly stresses existence of principles and revolving of the world. Its main function is explanation of phenomena which exist and their fitting into meaningful circumstances (An answer to a question why? — Kratochvíl, 1996, 17). For this purpose it frequently applies metaphysical, religious or cosmologic elements. A substantial feature of mythical narrative is referring to entities and facts which took place somewhere else and in the past (gods, punishments, etc.). Although they are present in a different space–time dimension, they can influence our existence. Through comprehension of these events we can grasp our own existence and its meaning.

1.3 Myth as a Form of Thinking

Some philosophers believe that a myth can be comprehended through plenty of aspects as figurative, *sedimented and conserved* knowledge of our ancestors. Although it might frequently seem so, explaining of myths and searching for allegorically expressed scientific facts in them are not always quite legitimate actions. That is why Ernst Cassirer views comprehension of a myth as *a form of thinking* and awareness of life. Together with Schelling's *Philosophy of Mythology,* he attempts to render myth rather as a form of life and explanations of the world.

A myth, like philosophy or science, uncovers principles and logos of the world similarly to science in plenty of aspects. Its gods

are philosophical principles and their logic is logos or a natural law. Mythical gods represent creatures never seen by anyone. And also, therefore, they form a basis of any narrative. A myth is often rebuked for its impossibility to provide evidence and blind faith in deity. However, fundamental science axioms are equally unprovable and also frequently do not come from "this world" (numbers, logical laws, etc.). And this fact concerns also the most exact sciences such as mathematics or physics. A point or a string from the string theory can serve as an example of existence of such entities in science. According to this theory, a basis of existence of a matter represents what we call strings. Nonetheless, a problem of their existence is that several dimensions of theirs which we believe they exist do not reach the size of the Planck length. The Planck length, however, represents the smallest possible dimension which can be basically observable or accurately determined (for shorter lengths or time intervals shorter than the time required for the light to travel through this distance (the Planck time), classical concepts about continuous space and time are not valid), therefore, the existence of the strings shorter than this size cannot be proved. In spite of this fact, it is the strings which should form a basis of everything what is observable. In a similar way, it is a point in Euclidean geometry which is sizeless, does not have a part and is only thinkable. Plenty of scientific axioms come from "the world" that is not so removed from the mythical one.

No solitary myth can clarify the whole order of the world. There are other myths serving this purpose and due to this reason they form a part of a context of other myths of a given mythology similarly as individual scientific theory assumes other theories and scientific disciplines assume a unity of science as such. Although, myths are structurally invariant to some extent, individual myths are basically non–transferable. It means that validity of their assumptions lies in the assertions of other myths of a given mythology. Only mythology attempts to provide an extensive panoramic view of the world. Use of myths coming from different mythologies collides with a problem of incompatibility of individual narratives.

1.4 Institutionality of a Myth

Another resemblance of a myth to science represents its *pedagogical* (Campbell, 1988, 22 — 23) and *institutional comprehension*. Myths (like science) cannot be practiced by everybody — initiation, dedication, receiving of academic titles, grants and responses in a science. In majority of cultures, telling of myths or similar narratives is entrusted to the most significant and wisest persons. Shamans, patriarchs, priests and grandparents or mothers within a family transmit information of myth to further generations similarly as the most prominent scientists administer scientific institutions. Scientists are obliged to transmit the acquired knowledge through foundation of scientific schools — own students also in a sphere of science. Myth similarly to science has its own language which has to be learnt, own heuristics and a method through which it approaches reality.

Not every narrative can become myth. As Karen Armstrong (2005, 14) writes, probability of myth does not lie in facts but in its *impressiveness*. Plenty of myths lose their convincingness and myth is not told anymore and subsequently vanishes (Jung, 2001, 52). If a narrative does not provide answers and a picture it portrays is not convincing anymore, it ceases to be interesting. That is why, as time moves on, these myths are modified, however it happens also due to conditions in which they are situated. Myths identically as scientific theories sometimes persist (Aristotle's logic), or on the contrary vanish (like alchemy or astrology), or become only a historical material and make way for new expositions.

In spite of the fact that there are a lot of differences between myth and science, I assume that especially thanks to similar objectives, aspects and persistence of several mythical elements in science (ontological status of mythical and scientific entities), a myth can be considered a certain form of proto–scientific knowledge (Feyerabend, 2000). Science and likewise myth predominantly want to provide a homogenous and convincing explanation of functioning of the world and our successful stay in it. It is true that myth and science use dissimilar methods, languages or outcomes and their institutional organisation is different, yet, they share roots and functions of their efforts — an explanation of principles of functioning of the world and a manual for successful survival.

1.5 Recommended Literature

VIGNOLI, T.: *Myth and Science*. The Echo Library, 2007, 71 — 107.
LÉVI–STRAUSS, C: *Structural Anthropology*. Basic Books, 1974, 206 — 231.
CASSIRER, E.: *Essay on Man*. Yale University Press, 1977, 72 — 99.

2. A Pythagorean Heritage

Key words: *number, evidence, proof, golden mean, method*

Pythagoreanism represents a perfect example of interconnection of myth, philosophy and religion not only thanks to its formal structure but especially due to indivisibility of philosophical and scientific attitudes from their mythical and religious background. The Pythagoreans similarly to other Pre–Socratic philosophers searched for a fundamental principle of construction of the world — *arché*, however, on the contrary to others, they found it not in elements or forces but in their relations and ratios — in numbers.

2.1 A Number — A Basis of Everything

The Pythagoreans were not the first who discovered a number and essentials of mathematics — those discoveries can be assigned to ancient Babylonians, Egyptians or Indians. However, they moved mythical comprehension of numbers to a metaphysical level and their approach towards knowledge separated mathematics from mythology (Whitehead, 1925, 41; Burkert, 1972, 401). They understood that almost any relations in the world can be expressed through numbers. We know that they dealt with an expression of such difficult phenomena as a pitch or a harmony and beauty. Nonetheless, a substantial discovery of the Pythagoreanism was comprehension of a number as a principle, and in this respect, number one has an irreplaceable position.

Number one is the smallest possible object. Everything that exists is like an individual — one. Certainly, it can be objected. Number one can be divided into halves but then instead these halves become the smallest possible objects of the world — one — and so ad infinitum. Everything that there is, exists thanks to this peculiar and at the same time only imaginary number one. Any other number consists of the ones. Number one represents every individual. The smallest possible area is a geometrical unit — a point. After all, for the Non–Pythagorean, Democritus also the smallest possible particle — *atomos* cannot be further divided. However, for the Pythagoreans number one is not anything tangible or concrete, quite the other way — it is a mere abstraction. No wonder, it became a real principle for them which was shown even a divine respect. It is clearly documented by a unit of economic value (currency) which can be so small that nothing can be bought for it, or that there is no medium of exchange having this value. Nevertheless, everything that has a certain value, has it thanks to and against it. Therefore, its ontological status considerably resembles mythical deities and this tradition lasts until the present day and one or the numbers represent a basis of any science virtually until nowadays.

The Pythagoreans identified one with perfection and deity. For them, one represented a symbol of unity and a whole against plurality and non–identifiability (Kahn, 2001, 59). It was not a number (the number assumes plurality — Fergusson, 2011, 114), but a basis for all other possible numbers (arché — Diogenes Laertios, 1995, 324). Number two (dyas — a line segment) was comprehended as a connection of ones. This connection explained presence but also dissimilarity of ones and thus two represented a female and double principle. It was only a connection of female and divine principle that created a real number, number three. It characterised a male principle and expression of a plane in geometry and also beginning, middle and the end, a soul, matter and three–dimensionality (Karamanides, 2006, 63). Magic and mystique accompanied the whole Pythagorean comprehension of the numbers: four as the first spatial object — tetraeder as a symbol of order, six as a symbol of excellence and fullness — contains its own divisors — and likewise ten containing a sacred tetractys (1+2+3+4), nonetheless the Pythagoreans discovered also relations existing among them which changed our mythical approach to knowledge to the scientific one. A pentagram — a symbol of the Pythagoreanism represents the best way how it can be documented.

2.2 Evidence and Proof

Ancient Greek comprehension of numbers was *visual*. Greeks frequently saw numbers and comprehended them as stones or quadrates, rectangles (Kaplan, 2011, 177 — 178) and triangles (four represents a quadrate consisting of one and a triangle, however, a triangle above four is 10 and a quadrate above four is already 16), numbers with a middle (odd) or without a middle (even). Visualisation and geometrisation of arithmetics enabled them a substantial shift from a myth to scientific knowledge. A possibility *to evidence* validity of given assertions through sight represented a significant feature of this type of cognition. I believe because I see that it is so. The Pythagorean science is based on evidence and *a proof* that distinguishes it substantially from mythology. The truth assumed by a myth cannot be proved, instead it has to be trusted. On the contrary, the Pythagorean truth can be proved.

As Petr Vopěnka claims (2000, 38 — 39), some knowledge is evident at first sight. We do not doubt its validity because we can see it (it is a self–persuation through direct cognition, vision). Yet, there are other phenomena which we have to learn to view and see what is not evident at first sight, or what exists, although we cannot see it. Thus, if we do not want to be only mythical believers, we have to find the validity of given knowledge by uncovering and comprehension of the seen things. This approach requires to know where and how to look. A problem of arithmetic or geometrical evidence is that we cannot be persuaded about individual knowledge

— we have to comprehend its validity on our own. And this can be achieved only by travelling around the world where knowledge can be found.

2.3 A Method as a Journey

> The Pythagoreans enriched knowledge with proofs which can be seen, if we take a journey of thoughts. To travel this journey (*methodos*) means to use a certain method. A teacher can describe the journey, nonetheless, everyone has to walk it on their own. And this is where a charm of the Pytharoean knowledge lies. It is accessible to everyone who walks the journey and everyone can be persuaded about its validity contrary to myth which is based on a narrative authority.

A secret hidden in a pentagon represents an example of this evidence. The regular pentagon holds the secret of the golden mean and knowledge on irregularity of a diagonal and a side. In other words: the diagonals of the regular pentagon mutually cross at a point which divides them under a ration of the golden mean (Vopěnka, 2000, 65). The golden mean was not only considered as the most beautiful ratio, at the same time it expressed also a relation of a line segment divided into two sections, i.e. the longer section has a relation to the whole line identical with a relation of a shorter section to the longer one (an extreme and middle ratio). Moreover, intersections of the diagonals create a new regular pentagon whose sides are shorter to the sides of the original pentagon in the golden mean ratio (ϕ) and this process can continue ad infinitum (similarly as with fractals). A peculiarity of the golden mean is its arithmetic value. It was on this mean that the Pythagoreans (Hippasus of Metapontum; Fritz, 1945, 242 — 264) shockingly found out that its value cannot be expressed by rational numbers, i.e. a ratio of a side and a diagonal is incommensurable. This secret disrupting the divine theory on nature of numbers or revealing existence also of other deities (irrational numbers) lead to decay of the Pythagoreanism and a greater desacralization of mathematics (after they did not manage to continue to conceal it). Similarly to the beauty which shamelessly shows off and overlooks everything else represents a pride (a symbol of the pentagon depicting incommensurability of the sides and diagonals arises only after the pentagon through which it was created is erased — Vopěnka, 2000, 66), science applying an assertion that a book of nature is written in a language of mathematics, however, not taking into consideration roots of mathematics, nature of numbers and their principles and showing no due respect is likewise vain. Science needs and requires a proof (logical one or confirmation through experience and facts), yet as well needs to believe (trust) in means leading to the proof themselves.

2.4 Recommended Literature

TATON, R.: *Ancient and Medieval Science. From Prehistory to AD 1450*. London : Thames and Hudson, 1957, 199 — 203.

HUFFMAN, C. A.: The Pythagorean Tradition, in *The Cambridge Companion to Early Greek Philosophy*, A. A. Long (ed.), Cambridge: Cambridge University Press, 1999, 66–87.

LIVIO, M.: *The Golden Ratio.* New York, Brodway Book, 2003, 12 — 41.

3. Platonic Legacy of Scientific Comprehension

Key words: *idea, uncoveredness, truth, geometry, self–persuasion*

In eyes of the philosophers and science historians, Plato does not represent a prototype of a scientifically oriented thinker, quite the other way. In comparison to his erudite student Aristotle, Plato is often portrayed as a non–scientific, philosophically and mythologically specialised thinker. His figurative almost mythical language, a strange theory of ideas, parables about cave and the sun or coachmen and also certain contempt towards science expressed in a parable about a section line are the reasons for depicting him this way. In spite of these facts, Plato influenced European science much more than we often realize and he did so in more than one field. The first field represents his epistemology and the theory of ideas which is related thereto.

3.1 Permanency of the Truth

Plato realised that if knowledge should be valuable, his propositions have to be *permanently valid*. What knowledge would it be, if it once claimed this, other time that, even if due to the changing truth validity of some assertion was doubtful already at the moment when you were asserting something about a phenomenon? That is the reason why things which constantly change and undergo modification cannot be subjects to scientific propositions. What sense would it make to study phenomena which are to change in a few moments and to say something what is not to be true very soon? I assume that it is this comprehension of knowledge that represents the main reason for postulating otherwise mythical theory of Plato's ideas.

3.2 Ideas and Ontological Status of Objects of Knowledge

An object of cognition should be objects which are eternal and unchangeable. However, if they exist, where did they come from, what is their ontological status and how do we view them? Philosophy textbooks tell us that they represent ideas (from Greek "eidolon" — image, to see) and are approachable only through reason (*Phaedr*. 247C). Yet, how do we know about their existence and can they be really seen somewhere? Geometry is an ideal example, proper for their comprehension.

In a real world, we hardly (if at all) encounter objects which would not really undergo modifications. A line segment drawn on a sheet of paper can serve as an example. Even if we do not take into consideration the fact that any ruled line segment is not completely straight — perfect, we immediately realize changeability of this object already when we even slightly crumple the paper where it is located. Such a line segment will not be a part of a straight line anymore because it itself is not completely straight. Thus, if we want know something about line segments we inevitable have to forget about objects of the sensual world and set off for the ideal world of thinkable objects. In this world, one can find line segments perfectly straight, endless straight lines and plenty of other perfect and unchangeable objects (*Rep*. 527B).

It is amazing how these objects become accessible to us. It is evident that we do not find them in the sensual world (Tait, 2002, 16). At least not directly. In spite of this fact, it is this sensual and imperfect world that mediates for us encounters with perfect objects. According to Plato, the whole cognition is recollection (anamnesis) and knowing is unforgetfulness — a–Léthe, which is also perfectly

explained by *Aha effect* of discoveries. If we recall our first encounters with geometry, we find out that sight of a real geometrical triangle was preceded by familiarisation with drawings somewhere on a board. The teacher was drawing various objects and asserted that they were triangles. However, if we identified them with the drawings, we did not notice the triangles. It happened only after we moved into the geometrical world of thinking in the drawing and through it. (The sensual object reminded us of an idea which we would subsequently recollect (anamnesis theory) and comprehend the object as a triangle). Geometrical objects come to our mind from emptiness, that strange thinkable world into which they subsequently vanish immediately after we stop thinking. Yet, it seems that they continue to persist in this world because one can get back to them anytime and thanks to their intangibility they remain undistorted and unchangeable (Vopěnka 2001, 39 — 40). Moreover, when we learn how to move in this world, we can also find objects which cannot be seen in an ordinary life or which have not been shown to us by anyone and there is nothing in the sensual world that would remind us of them. For instance, Perfect Platonic solids represent such objects. A regular tetrahedron, hexahedron, octahedron, dodecahedron and icosahedron are objects which are not only formed from regular triangles, quadrangles or pentagons, all its peaks can be inscribed in a sphere and moreover, connecting lines of their side centres form the Platonic solids once again. Plato was well aware of this fact and that is why he incorporated it in his element theory (Earth — cube, tetrahedron — fire, octahedron — air, water — icosahedron and dodecahedron — universe, *Tim*.54d — 55c), peculiar chemistry (water (icosahedron) consists of two particles of air (2x8 sides) and one particle of fire (4) — *Tim*. 54c–56d), and also into construction of the whole universe.

3.3 Methexis

The second great message connected with Platonic ideas represents his theory on *parousia* and *methexis*. Plato believed that ideas form an object of real cognition. The fact that this approach can be applied to logic, arithmetic and geometry or to other exact approaches is understandable and a great part of logicians and mathematicians really openly profess Platonism. Surprisingly, Plato's legacy can be found also in natural sciences, for instance, in physics, medicine (especially in anatomy) and also in humanitarian sciences — in psychology, ethics or law.

What a physicist describes is mostly not a real liquid but *ideal world* principles — an ideal gas, liquid, movement in a vacuum, etc., because the real substance frequently contaminates and makes observations impossible. Thus, in order to uncover real principles one has to penetrate into the ideal world similarly to a student of anatomy who does not learn about their own or neighbour's body, instead an ideal human body deprived of individual, racial and frequently also of age characteristics represents a research object. It is this body which is a model on a basis of which we analogically infer an organisation of any human body. Plants or animals can be studied in a similar way (that is why there is cynology not taking into consideration breeds and individual differences of particular dogs...) as well as human psyche, society and other (Platonic) standards and principles valid in it. Idealisation of research objects is not only an effort to purify issues from insignificant matters, instead, it represents a method how to discover the most general formulas and principles of construction of the world (Penrose's world No. 1).

3.4 Science as Uncovering of the Truth

Plato's comprehension of the truth represents the third and probably the most significant legacy. He views the truth as an idea *independent of a subject* and a human being can uncover it. Thus, the human being is not a creator of the world and truth, instead, rather the one who uncovers it. A Platonic scientist discovers rules, does not constitute them and therefore believes that we get to know the world (the eternal one) as it truly is. It follows that the truth cannot be possessed but only viewed and even this can be performed only partially, from an individual viewpoint. An overall view of the truth is not possible, although it is implicitly assumed that there is only a single truth and individual partial knowledge cannot be totally inconsistent. Therefore, there is also only *a single* knowing and special scientific disciplines retrieve the same reality of the world nonetheless from dissimilar aspects. However, by collecting all valid scientific knowledge we create a homogenous and complete picture of the world.

Plato realized that scientific knowledge applied to ideas participated by individual physical objects. It follows that individual science can be created actually about any generic term (anthropology, sociology as well as oenology ...). Nonetheless, there is a certain hierarchy among sciences reflecting an extent of abstractness or participation of more concrete ideas on those more general ones. That is why it seems that special sciences represent a lower level of knowledge (closer to crafts than to philosophy) because they do not reflect either overall links or their own principles. Contrarily, those most abstract and general objects such as ideas on beauty, good and the truth form a peak of cognition.

A craftsman does not have to ponder about reasons for procedures he uses and search for their veracity and legitimacy in a total context of construction of the universe. Likewise, a physicist, if he examines objects as objects, cannot render the truth exactly, if he does not purify his research objects from impurities, from their substantiality.

> A scientist has to penetrate through a veil of substantiality covering the truth and clouding real character of an object

— its ideal being (e.g. corporeity). Thus, if a scientist wants to get to know the truth about his research objects, he has to free them from everything concrete because science based on a concrete matter is not possible. However, every object participates not only on its own idea (a ball on an idea of sphere) but also on more general ideas (curvature, convexness or concavity, orbicularity ...) and its complete cognition is possible only after we get deeper to its most intrinsic and general grounds. Those enable us to penetrate to the most general principles actually only after they cannot be materially characterised anymore.

That is what Newton did several centuries later when he was pondering about tangible objects which he freed from any material characteristics and comprehended them only as forms of tangible points. So if a physicist wants to discover general principles, he has to formulate his research, for instance, by arithmetization or geometrisation. A pure form of this formal physics — statics or kinetics — is then arithmetic while geometry is the pure form of optics. Not coincidentally, it is geometry (deprived of any matter) which has become a prototype of perfect and the first science. Euclid who was a student of the Platonic Academy (despite the fact that his geometry represents elaboration of axiomatic and deductive method characteristic of Aristotelian comprehension of science) embodies its most significant representative and a core of (his) geometry bears mainly Platonic residues.

Self–persuasion represents an amazing feature of geometry. According to the Platonic viewpoint, radiance and clarity come from closeness of general ideas to an idea of Good (Sun), i.e. the most fundamental truth is always more evident for us. Geometrical truth is obvious and its evidence does not require any further proofs. What can be more evident than viewing an idea in its total bareness and uncoveredness (the truth as alétheia) through a sight of reason? Reason might not trust the eyes, nonetheless, it has to trust itself. Therefore, rational evidence does not require any further proofs. They are the simple truths. It is possible to require a proof only if we assume that what we view does not have to be the truth and thus there is also another possible evidence. However, viewing itself does not mostly offer these reasons for a dispute (ambivalent explanations are characteristic of modifications of a view — e.g. change of "gestalt" not due to a particular view itself). Because an object either participates in an idea or it does not, and this fact is simply manifested. We just view it, we do not constitute it. Thus, it depends only on us whether we are able to view it correctly and see something, or not. Equally, it is only up to us whether we can approach it in a way enabling us to view the evident evidence (and also those matters which are hidden at first sight) through consecutiveness of steps. Thus, if we want to get to know the world, we have to enter it through our thinking and analogically (according to Plato and an inscription written about his Academia) if we want to practice science: Let no one untrained in *geometry enter!*

3.5 Recommended Literature

PLATO: *Republic (Rep. 509D–511E)*, Basic Books, 1991.
LIVIO, M.: *The Golden Ratio*. New York, Brodway Books, 2003, 62 — 91.
HARE, R. M: Plato. In: TAYLOR, C.C.W., HARE, R. M., BARNES, J., THOMAS, K.: *Greek Philosophers: Socrates, Plato, Aristotle (Past Masters)*. Oxford : Oxford Paperbacks, 2001, 133 — 190.

4. Aristotle and the Power of Negative Knowledge

Key words: *categories, syllogism, negative knowledge, law of contradiction, quasi necessity*

In textbooks dealing with philosophy and history of science, it is usually Aristotle who is determined as the most significant representative of ancient thinking development not only due to his systematic classification of sciences (*Met* VI, 1, 1025 b25) and a development especially of physical and astronomic knowledge, but mainly thanks to his formulation of a special logical and methodological inventarium which became a frame of scientific research. Especially scientific empiricism (Lewes 1864, 109) contrasting with Plato's rational and speculative method is traditionally assigned to Aristotle. Although inclination to sensualism and empiricism represents a characteristic feature of Aristotleanism, I assume that a real core of efficiency of the Aristotelian science lies in his logical method and realistic constructivism.

4.1 Accusations of Essence

While Plato believed in inborn knowledge in a form of anamnesis, Aristotelian gnoseology refuses this theory as unfounded. Aristotle claims that our cognition begins with a sensual experience and this assertion influences also his comprehension of reality and science. While Plato views eternal ideas as real, for Aristotle a sensual world reality is real. The way we think about it is subject to ideality

which is, however, made by the world reality and also by ourselves. Aristotle clearly discusses it in his text *The Categories* where he points out to that fact that knowing depends on a language we use to express external reality. The term *kategorein* (accusation) itself means that we do not render reality of the world as such but rather that we create a parallel mental (language) structure to it and its task is to describe and copy the world. Our thinking is adequate when our concepts through which we talk about the world correspond to an actual situation of the world. Aristotelian comprehension of the truth viewing it as a language entity (the truth resides in conclusions, not in things) indicates the same, and thus science becomes a dynamic human activity — not a mere revelation and also active creation and formulation of ideas about the world. The vital thing is that when creating conclusions about the world, we have to let ourselves to be guided by the world (sensual experience) and *rules for correct reasoning* (Organon) and thus to ensure concord among things and our thinking about it. However, accusations (categories) are true only if they portray facts about reality that are really true. The first substantial change in his comprehension of science is then a turn to the sensual world and an attempt to copy it in a realm of thoughts.

4.2 Negative Knowledge

A discovery of meaning of *negative knowledge* symbolised the second substantial pillar of Aristotelian success. While for Plato the truth was characterised by direct evidence of idea (we know only what we positively evidence, what we do not evidence does not exist), Aristotle knew how to gain knowledge also from what we know is not true. Negative knowledge (in spite of the fact that it directly does not state how a thing exists but what it is not) thus could have become significant means for expression of a real state of things provided that we observed certain rules of correct reasoning. His whole *Physics* can serve as an example of efficiency of this approach.

In this (for science) crucial text, Aristotle ponders about being and number of principles. He logically deduces that there might be a single principle or more principles. A possibility that there might be no principle does not even thematize because experience shows that things exist and therefore there must be at least one principle forming a ground for existence of things (nonbeing does not exist). If there is more than one principle, their number is then either finite or non–finite. Through a simple reasoning, he comes to the conclusion that a possibility of searching for common features in things (science can be only about the common, what is individual does not represent a subject to science) proves existence of finite number of principles. Apart from the fact that Aristotle finally comes to two or three basic principles, it is remarkable that his reasonings are based on an indirect proof — a proof through contradiction.

Quasi necessity (only what is necessary can be known scientifically) represents a fundamental feature of his logic. Through negations, negative knowledge can be turned to positive one and it can be further deduced. The principle of quasi necessity imparts certainty of Platonic evidence to the negation of negative knowledge.

4.3 Deductive Inference

Sourcing from syllogism (inference — argument), *a deduction* forms a foundation of Aristotelian logic. The inference consists of premises and a conclusion arising therefrom. The premises represent assertions assigning certain predicates to a subject. The premises have to be positive and affirmative and if they are true, the conclusion of a correctly deduced inference is then necessarily true. In science the first premise should be immediate, better known and more original than the others and represents a source of validity of conclusion (*Anal.Post.* I.2 71b20–72a5). In a similar way also the second premise has to be true, nonetheless, its subject (middle term) is not present in the conclusion of inference. It is this

premise that embodies the main real subject of scientific research. The conclusion which we get from syllogism is a consequence of deduction arising from both preceding premises.

According to a type of a quantificator (all or some) and also the fact whether we assign a predicate to a subject or deprive it from it, we distinguish four types of syllogisms. An inference scheme — mode — is created when we replace concrete terms in the inference with variables thanks to which we can decide on validity of infinite number of inferences which fall within this mode by a single decision on validity of a given mode.

Syllogism consisting of premises: 1. "All Greeks are people." and 2. "All people are mortal." represents a good example of this type of thinking. A conclusion of this syllogism is knowledge that "all Greeks are mortal" which is valid if premises No. 1 and 2 are true. Yet it is questionable how we know something about veracity of these two main premises.

The assertion about affiliation of Greeks to human kind is either a purely nominal definition or knowledge which is inductively and intuitively viewed. Aristotle had to discover features which connect Greeks with other members of our kind and he could do so only on a basis of experience as well as through logical comprehension of a meaning of a term: human being.

However, the second premise is even more interesting. It claims that all people are mortal and Aristotle could not deduce this fact only from experience. He does not have experience with all people of his era or with all who lived so far and even he cannot have experience with people who have not yet been born, although he foresees their death, as well. Nevertheless, we consider this premise valid. So where do we know it from? Once again it seems that it is from *intuitive induction*.

Aristotle himself does not consider induction a scientific method because it does not provide a final proof. In spite of that, he does not conceal that we have certain explanatory outcomes at our disposal which determine our acceptance or refusal of given premises.

Observations and experience or knowledge of antecedents represent this set of basic epistemological positions. On their basis and methods and analyses of facts we attempt to create a consistent explanatory system — assertions enabling us clarification of problems in a way which will make them correspondent with the rest of so–far accepted assertions. A task of any premise — thesis — is to explain phenomenon in a way which would enable us to integrate it into a group of accepted knowledge.

4.4 Axioms, Archai and Endoxa

In this context Petr Vopěnka speaks about a thesis as expansion of an explanation of the already experienced world to a world which we have not experienced yet. At the same time, we assume homogenity of the world in front of and beyond a horizon of acquired experience and identity of its construction and law which are valid therein. And this entitles us to use established patterns for new experience, as well. On the contrary, validity of hypothesis cannot be supported by a preceding experience, only by a mere logical possibility which could serve for explanation of existing phenomena. However, the hypothesis also draws from the introduced explanatory outcomes of logic and from previous experience. Whether a given thesis or hypothesis comes to our mind (in Platonism "we discover it" or "it crosses our mind" — thus, it exists independently of us) or why we should use this thesis and not another one lie more in intuition than in the deductive inference.

A crucial point of Aristotelian scientific method (*apodeiktikos sylogismos*, not of syllogism (Smith, 2009, 51), Barnes, 1969, 50) are represented by *axioms, archai* and *endoxa*. It is them that form a backbone of the whole axiomatic and deductive system. Axioms can be considered the most general foundations of any knowledge but also premises (Smith, 2009, 69). Archai are essential hypotheses of individual sciences while endoxa embody accepted or scientifically uncontested assertions (Irwin, 2001, 28). It seems that

Aristotle could do with a few observations (theoretically with only one) in order to formulate assertions which were then valid as patterns for a general explanation. According to Platonic comprehension, it would be possible to identify axioms and archai with ideas, nonetheless for Aristotle they are implicit postulates or assertions which we create intuitively. So they are not independent of us. Therefore, veracity of axioms cannot be proved a prori — quite the other way, they themselves are a condition of validity of all assertions which have been deduced from them (*PA* 24b18–20). Veracity of axioms is proved mainly through their successful application in explanation of a problem. If the given explanation is explicatory, the axiom is confirmed. However, as the time moves on, it can happen that we will identify originally valid axioms as false. Elimination of even one postulate can make the whole explanation invalid or create a completely new framework of explanation (as it happened in history of non–Euclidean geometries). In this context, science does not represent discovering of rules of the world; instead it is rather an explanation of the already known facts (Barnes, 1969, 67). That it why especially the middle term of deduction belongs to it in the structure of Aristotelian syllogism.

4.5 Knowing of a Proof — a Scientific Proof

In *Posterior Analytics* Aristotle implies that "we know only when we know why" (*Anal. Post.* I, 2). Therefore, an important part of Aristotelian science represents a proof. The proof (direct, indirect, branched, with an idea construction) cannot be optional but has to follow certain principles — logic. Reason is not an uncanny oracle, it follows principles of thinking. The most important are the law of contradiction — reason cannot contradict itself and the law of excluded middle (exclusi tertii principium) — a thing has a property, or it does — Platonic relic.

However, it is amazing that principles of logic cannot be proved, instead they have to be accepted. Every premise in a proof has to have a clear, accepted element which is not contested, otherwise the proof is invalid (otherwise it would be proving through unproved facts what causes petitio principii). It is also possible that certain proofs can be applied only to certain objects and a proof as such is not transferable (special disciplines autonomy). On the other hand, owing to Aristotelian comprehension of a proof of veracity of axiom on the basis of applicability of explanation deduced from it, proofs deduced from identical or complementary axioms mutually (psychologically) support (subalternation)themselves. It is this effect which helped Aristotle to create a scientific system of the world which survived for almost twenty centuries.

4.6 Recommended Literature

ARISTOTLE: *Posterior Analytics*. CreateSpace Independent Publishing Platform, 2012.

EWANS, J. ST. B. T.: The Influence of Prior Belief on Scientific Thinking. In: CARRUTHERS, P., STICH, S., SIEGAL, M.: *The Cognitive Basis of Science*. Cambridge University Press, 2002, 193 — 210.

BARNES, J.: Aristotle. In: TAYLOR, C.C.W., HARE, R. M., BARNES, J., THOMAS, K.: *Greek Philosophers: Socrates, Plato, Aristotle (Past Masters)*. Oxford : Oxford Paperbacks, 2001, 222 — 288.

5. Aristotelian Picture of the World

Key words: *motion, peristasis, homocentric spheres, axioms and postulates*

An inductive and deductive nature of Aristotelian thinking and coherence of individual axioms enabled an explanation of the world portraying all important spheres of scientific research. A basis of Aristotelian scientific approach represented his logic. However, its employment can be viewed best in physics (as a prototype of the first natural science in modern understanding) and in Aristotelian theory of motion.

5.1 Science Classification or Determination of a Research Subject

Contrarily to metaphysics (whose subject are eternal and immovable essences), temporal essences represent a subject matter of physics. Similarly as a mathematician, astronomer and musician (a subject of their interest are eternal and movable essences), also a physicist focuses their attention to a motion, thus to a change. Yet, physics deals with everything whose cause comes exclusively from nature (*Phy* II, 192b), it focuses on the movable and changeable.

5.2 Theory of Motion

Aristotle believed that *motion* represents every *change*, i.e. a change of position as well as of ways of existence of things. Such a broad comprehension of motion enabled to study any changes without distinguishing between organic and inorganic essences. On the other hand, it inspired him to think about potentiality and implementation. He comprehended motion as implementation of potential of a body (*Phy* III, 201a). Therefore, in principle two basic types of motion may be distinguished. The first one is a natural motion whose cause is hidden in a moving object itself. The second one represents imposed motion and here the cause of motion of a body is located outside the body. Existence of imposed motion proves inevitability and primariness of existence of natural motion and Aristotle focuses his attention especially thereon.

His *theory of natural place* forms a basis of Aristotelian natural motion. Similarly as plenty of other predecessors of his, he assumed that correct comprehension of natural motion of objects depends mainly on comprehension of substances the objects consist of. Ancient science and philosophy recognized four basic elements (earth, water, air and fire) which as such cannot be found in a pure state anywhere. What we encounter in a common practice are their mixtures, and bodies differ especially in ratios in which the individual elements are represented in them. Dissimilarity of individual ratios causes a difference of primary qualities of individual solids. Earth is cold and dry, water — cold and damp, air — hot and damp, and fire — hot and dry. That is why also bodies have properties depending on the representation ratio of elements they consist of (from Aristotle's view point, mathematics is not natural science because it does not take into consideration material composition of things). However, the vital thing is that Aristotle deduced through his intuition that each of the introduced elements has its natural place in the world and thus bodies, if they are not influenced by anything else they head to a natural place which represents a resultant of effects of these elements in an object. Heavy ones (earth, water) head down and light ones (air, fire) upward. So if we throw a pebble into water, it sinks to the bottom because it consists more of earth than of air, however, it does not get through the bottom

because in comparison to the bottom there is smaller amount of the element of earth in the pebble. Similarly, a paper floats on the surface until air present in it is not pushed away by water and it gradually falls to the bottom. Aristotle believed that a natural place of earth is in the centre of the universe and owing to the fact that our planet consists mainly of it, the Earth resides in the centre of the universe. There is water (seas) around it, then air and fire at the top. These four elements correspond to four basic motions (upward, downward, onward and backward) characterising linear motion. However, it cannot be endless because it must meet a boundary somewhere which represents the celestial sphere. Moreover, perfect rectilinear motion does not exist in the sublunar world.

However, it is completely different in a supra–lunar sphere. Perfect cyclic motions can be observed in a space above the Moon. Existence of these motions observable also from the Earth must hide in itself other reasons than natural motions of sublunar solids. Therefore, ancient thinkers cogitate about the fifth element which embodies aether *(quinquesentia*). Also Einstein still believed in existence of this medium at the beginning of the 20th century. Due to its extremely soft nature, aether causes absence of negative effects of other elements on motion of heavenly bodies and those can move in perfect circles.

5.3 Causes are a Scientific Subject

Aristotle realised that every motion has to have its own cause. And it is the theory on causality (from his viewpoint on understanding of material, formal, efficient and final cause) which represents a foundation of our modern comprehension of physics. A cause of motion of a thing has to reside in the thing itself or in something else what makes the thing move. And this effect of a cause on things forms a ground of his theory of a contact effect and *peristasis* theory.

Aristotle assumed that an external cause can act upon a body only if it touches somehow. It might be done only through a direct contact or mediation of the contact through a whole chain of other contacts. Owing to this reason (but also other ones — compare *Phy IV* 6–9) Aristotle does not allow a possibility of existence of a void because the void would not enable existence of motion equally as its explanation. A contact mechanical effect is intuitively comprehensible. However, how to explain motion of a body which I will, for instance, hurl from my hand? Aristotle's reply is mediation of a contact through replacement of air elements surrounding my arm which have to make way for a stone hurled from my hand in a way enabling particles before the stone to push away particles on its sides and those to push away particles behind it, thus finally, the stone is pushed by the air particles residing between me and it and that is why it flies also after it leaves my hand. Yet, owing to an effect of individual elements in the stone, its whole motion consists of imposed motion initiated by a mediated contact effect of my hand and search of the elements for their natural place which (due to a mechanical effect of the air elements in all directions) finally causes that the stone stops. So, Aristotle understands locomotion mechanically and points out to a need for a mover. It is required not only in case of explanation of mechanical motion (a need for the first mover) but also for giving reasons for motion of entities capable of self–motion. Although they represent a source of their own movement, they are not a cause of their own existence. As a result, also a creature gifted with entelechy needs their cause (parents) which likewise has its own cause until we get to the first unconditioned mover.

Aristotelian conception of the universe similar to Homer's and other ones: assumed except for a sophisticated organisation (the Earth, water, air, fire, the Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn, eighth sphere of fixed stars, 9th crystal sphere, 10th celestial sphere) also a metaphysical basis of existence of bodies and their motion. Those might have been individual movers of particular bodies (gods, angels, there were 47 of them or 54 (North, 1995, s. 84) or eventually the first mover who resided behind the celestial

sphere. And thus a research of physical and astronomic axioms led their users to a need for a proof of existence and effect of the God as another axiom of scientific explanation of the world. It can be clearly seen in the third relatively complete sphere of classical science — in Euclidean geometry.

5.4 An Axiomatic and Deductive System — Euclid's Geometry

Euclid's geometry formulated within thirteen chapters of his *Elementa* embodies the cornerstone of European science. Thanks to its method and structure of the text it perfectly fulfils Aristotle's requirements for clarity, demonstrativeness and especially deductiveness of scientific knowledge. Euclid commences his reasonings with 23 nominal definitions which are followed by five postulates — requirements. The first of them asserts that we should have two determined points and those can be connected by a single line segment. The second one claims that the line segment can be lengthened in various lengths on a given side; however, any such two lengthenings will not be concurrent. The third postulate expresses the fact that a circle crossing a given point can be circumscribed around the centre and the fourth one asserts that all right angles are mutually equal. The five postulates are completed with an assertion that if we have a line and a point which does not form a part of it, only a single line parallel with the given line can be drawn through it. A rarity of Euclid's geometry represents the fact that if we accept the five given postulates, thanks to them and through them, we can construct everything what can be construed in Euclid's geometry. And that is basically everything what can be found in a world of classical geometry. An exception is formed only by sporadic problems which cannot be created via classical Euclidean geometry (the angle trisection, Delian problem — doubling the cube — proportion with four unknowns, squaring of a circle and construction of some regular polygons) yet, scholars found out about their existence and insolvability only gradually. Therefore, it is amazing that from such a small amount of basic outcomes such a great pleiad of assertions can be created being not only true but their veracity can be proved through their construction.

However, if we speak about construction in geometry, it is only partially true. A great part of geometrical objects (lines, rays, parallel lines) falls within the category of entities which are never completely viewed, and that is why we can never construct them completely. A line is endless similarly as its half (a paradox). One of the main knowledge deduced from postulates implies that two parallel lines cannot intersect anywhere. Not even in infinity. In order to prove this fact we need to see (at least in our mind) as far as infinity resides. Yet, we cannot do that. Therefore, we need some other guarantor who can verify and prove validity of our postulates for us. And this creature has to be some superman, basically the God. According to Petr Vopěnka, that is the reason why even the most enlightened ancient scholar believed in Olympic gods (Vopěnka, 2000, 183).

> Axioms from one sphere create a relatively autonomous unit of assertions, however, it is remarkable that at the same time they confirm validity of assertions from other area by completing a homogenous unit of mutually (at least at first sight) non–contradictory explanations of the world. Logic, Euclid's geometry, Archimedes' statics and Ptolemy astronomy thus lead us to a group of theological and metaphysical axioms which became a basis of theology, a later central discipline of classical Aristotelian science. And it was internal consistence and mutual support of individual spheres that enabled to form a system which — with small modifications — survived centuries.

5.5 Recommended Literature

ARISTOTLE: *Physics*. (book I: Chapt. 1–st, book II: Chapt.: 7 — 9, book III. Chapt.. I) Oxford University Press, 2008, 9 — 10, 48 — 55, 56 — 59.

HAKINSON, R. I.: Science In: BARNES, J. (ed): *The Cambridge Companion to Aristotle*. Cambridge : Cambridge University Press, 1995, 140 — 168.

EUKLID'S *Elementes. Books I–IV.* Green Lion Press, 2002, 1 — 98.

6. Theology and Medieval University Criticism

Key words: *lectio, comments, criticism, quodlibet disputes, antiperistasis*

A conventional cliché characterises the science in the medieval period as the dark ages (Grant, 1974, 3). A reason for this represents especially a preference of a speculation to an experiment and empirical research, and mainly inferring, adding and elaborating of individual elements of Aristotelian science, which drew attention to metaphysical and theological scientific moments. No wonder then, it was theology that became the royal discipline of scientific thinking as the time moved on. A theologian not only substantiated existence of individual entities and phenomena (causa efficiens) but also their meaning and purpose (causa finalis). He proceeded from an assumption that knowing of the both types of causes is not only required (for comprehension of a total meaning of facts) but it is also possible (Leinsle, 2010, 131 — 133).

6.1 Theology — Expansion of Science with God

Legitimacy of an opinion on knowability of transcendent principles came from two different types of arguments. *The theory of homogeneity* and identity of world principles in the world we experience as well as beyond its horizon represented the first one. Ancient thinkers assumed that principles which the nature follows in their world are universal and therefore, they will be valid also in spheres which they have not experienced yet. Their experience with nature often confirmed this assertion and that is why they dared to apply their knowledge also to a realm beyond a horizon of possible experience and thus to deities, as well. They assumed that the world is as it appears to us just because it expresses particular characteristics of its creator/s, even that its purposes can be read therefrom. *Analogy* and reflection theory formed an essential method of cognition. Especially with the arrival of Christianity proceeding from a premise that God created nature and a human being in his own image, it was comprehended that God can be explained on the basis of his creation and thus that God is not only knowable through his creations but his creations are similar to him to a certain extent. Lull's theology assuming an identity of world structures on all its levels with a relation of God's properties characterising his essence can be introduced as an example of an elaborate application of the theory of reflection. In the similar way, Thomas Aquinas applies Aristotelian "proofs" of existence of God using an analogy between our thinking about things and essentialness of existence of the "First Mover".

The second reason to confide in knowability of God was Aristotelian logic. It showed that logic gives us a powerful tool not only for cognition of what is true or untrue but at the same time represent means of how to find out whether something is real or at least possible. Entities which are scientifically disputable are impracticable, as well. Therefore, we can exclude facts and properties which contradict with logical certainty and it can be pondered similarly about God's properties. It is possible that a cause might be completely different from an effect which arose. This fact led theologians to infer logic and characteristic of God from logic of a thing, moreover, they subordinated him to reason itself in plenty of cases. Thus, on the basis of logic and a power of negative proofs, a lot of scholastic philosophers could ponder not only on God's existence (Anzelm) but also on his attributes. A good, although historically new example is represented by Bruno or Leibniz's analysis of the world proceeding from acceptance of God's properties (omnipotence, goodness...) which do not allow even God to create the world differently from what our logic prescribes.

6.2 Institutional Spreading of Science

With establishment of universities, theology reaches the very centre of scientific cognition and also becomes its peak (Leinsle, 2010, 120). This fact is documented by a structure of academic education assuming that a basis of a homogenous explanation should be represented by art (philosophy) serving as a general propedeutics of further education with practical application either in medicine or law. It was theology completing academic studies and requiring also the longest period for preparation and study itself that should have represented the peak of the studies. Comprehension of a university as a single scientific community and a homogeneous scientific explanation of the world was a significant feature of medieval academic study. Students and teachers shared this common world and assumed consistency and unity of individual knowledge and disciplines which was documented by open and quodlibet disputes. And it is an educational method that represents a vital moment of medieval education.

6.3 *Lectio, Questio* and Criticism

As Jacques Le Goff (1999, 84) states, a medieval study consisted mainly of close reading of relevant texts (*lectio*) and their subsequent commenting. A task of a lectio was not only familiarisation with a text followed by its comprehension but especially uncovering of its most hidden meaning and purposes. Medieval intellectuals thoroughly studied Aristotle in order to apply it as a basis of their individual thinking and therefore they did not only explain Aristotle's thinking, they also attempted to problematize and develop it. Thus *quaestio,* during which a student does not examine only consequences of master's thinking but also problematizes

his very outcomes, developed *from lectio.* As a result, he can see what his master did not, or infers consequences which remained concealed for the author and brings new conclusions (*determinatio*) and solutions. Finally, it was the text criticism that became the strongest instrument of their comprehension and subsequent progress in science. Later in the 13th century, questios freed from the original text and became individual ideological "happenings" and their mastery culminated in performance of quodlibet disputes. Their purpose was to develop and substantiate accepted theses against anyone and any objections.

A basis of medieval academic education system points out to the fact that critical inferring and problematization of accepted assumptions (e.g. through deduction or *pro et contra* method) enable their users to violate and test validity of individual scientific assertions. Generally, self–persuasiveness of Aristotelian conclusions arises from absorption of a phenomenon by its explanation — explanation of some phenomenon draws our attention to what can be seen in the phenomenon and what suits it and not to facts which contradict it or do not define it (Vopěnka, 2000, 240). That is why explanation enables comprehension of an explained fact, yet, at the same time it covers other aspects. Nevertheless, serious arguments pointing out to logical or factual shortcomings and necessity of re–evaluation of individual opinions or efforts to modify them start emerging over time. A set of objections against Aristotelianism coming from a circle of Aristotelian thinkers themselves represent an excellent example of such process.

6.4 Contradictory Knowledge

Aristarchus's assertion about heliocentricity of the universe might be included in the first serious objections against Aristotelian physics. Aristarchus assumed that the Sun represents the centre of the universe, however, his attitude contradicted a general physical theory and therefore it was pushed to a periphery as a mere speculation. Seleucus from Seleuceia was the only one who attempted to prove his assertion (North, 1995, 86). Similarly, Philoponus in his *Commentary on Aristotle's Physics* from the 5th century AD pointed out not only to factual but also logical shortcomings of Aristotle's peristasis theory describing motion of celestial (Wildberg, 1988, 237) as well as thrown bodies. It assumed three types of motion of air particles before a body and its subsequent pushing; nonetheless, it did not explain why a human being has to be in contact with the object at the beginning of the whole process. Philoponus realised that if only the pushing air should be the cause of continuation of motion of the thrown body, why cannot we move the body also without a contact, just by making the air move? Moreover, according to the *antiperistasis* theory it is evident that an environment (air in it) represents rather an obstacle than a source of motion and motion could exist (even more easily) also in a vacuum (Piaget, Garcia, 1989, 15). Philoponus' ideas were later elaborated by Avicenna, Jean Buridan (Buridan, 1974, 276) and Nicolo Oresme. The Medieval mechanists notified that inertia of motion of water or mill–race contradicts Aristotelian theory because the wheel continues to move also after an effect of water or air propelling it stops. Similarly, a shape or sharpness of an arrow does not influence its motion, and a ship moves inertially upstream for a certain period of time even after oars are pulled out of water. But mainly how come that air which can move the whole ship (sailing boat) does not wipe a human being off from its deck although he is markedly lighter? Moreover, an experience of a long jump rather affirms that the air offers resistance and does not propel us (Piaget, Garcia, 1989, 18).

Although today we rather trust Aristotelian critics, during the time when they presented their objections, their argumentation was not accepted. One of the reasons represented the fact that Aristarchus's opinions were preserved only indirectly and tangentially or in a simplified or distorted form. (We got to know about Aristarchus mainly from Archimedes and Philoponus' ideas were introduced especially through their critique written by Simplicius.)

However, except for that they opposed explanatory outcomes of the rest of physics and they themselves did not provide better or broader explanation of physical phenomena. Due to that and the mention "absorption" of a phenomenon by explanation, Aristotelian opponents were perceived as those who mislead or bring anomalous experience. Yet, later their theories might have become productive in the same way as Buridan and Oresme's impetus theory which except of criticism of the peristasis theory (antiperistasis conception) brought also a platform enabling new explanation of motion.

Gradual emergence of *contradictory knowledge* and experience partially took place also in other spheres of cognition, however, a declaration of a Parisian and later Canterbury bishop (1277) criticising mortality of an individual soul and especially problematic existence of freedom in causally determined comprehension of motion represented the really first crucial impulse for revision or refusal of Aristotelianism. Therefore, it is not surprising that the most vital revisions and modifications of Aristotelianism come mainly from a theological and university background. Franciscan scholastics, empiricists but also Nicholas of Keus radically modifying our comprehension of God (limiting abilities of human being to get to know God) nonetheless preserving essential construction of the world can serve as an example as well as Giordano Bruno who on the contrary thoroughly believes in attributes of God's existence and it is on their basis that he is forced to substantially revise an image of world construction in which we believe.

A medieval university taught thinkers thoroughness and elaboration in argumentation methods. Thus, it educated critics of Aristotelianism who could infer consequences of individual ideas and prepare environment for revision of the necessary and refusal of the erroneous. Paradoxically, Aristotelians educated those who disproved Aristotelianism in the same way.

6.5 Recommended Literature

ASHWORTH, E. JENNIFER, "Medieval Theories of Analogy", *The Stanford Encyclopedia of Philosophy* (Fall 2009 Edition), Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/fall2009/entries/analogy–medieval/>.

SPENGER, I., INSTITORIS, H.: *The Malleus Maleficarum.* New York : Cosimo, 1997, (q I , XII — XVIII), 1 — 12, 66 — 88.

LE GOFF: *Intellctuals in Middle Ages.* Blackwell, 1993.

7. Francis Bacon and a Significance of Induction

Key words: *criticism of syllogism, observation, experiment, induction, generalisation*

An advantage of axiomatic and deductive system of sciences is that we need only relatively short time for deduction of all relevant (or at least those most important) knowledge which the system offers, if there is a limited and known number of axioms and basic postulates. Aristotelian science developed its knowledge very quickly nonetheless stopped brining new findings and started to stagnate. Except for its slight extension especially in stoic logic and elaboration of theology and astronomy, it did not provide almost any new knowledge in other fields. That was the reason why already towards the end of scholasticism (Franciscan empiricists) and predominantly with the arrival of Renaissance the criticism of stagnation of science emerged which, proceeding from deduction, met its own limits and boundaries.

7.1 Criticism of Deductionism

In *Instauratio Magna*, Francis Bacon criticises speculativeness of science and its sterility in comparison to trade and crafts. However, not only lack of new knowledge but especially the deductive method of his predecessors form a basis of his criticism (Bacon, 1974, 116 — 128). A drawback of deductionism is that it proceeds from vague and dubious axioms or first findings. A conclusion (*determinatio*) not only does not bring totally new knowledge, it merely provides what the first or the second premise contains. And also veracity of premises itself becomes problematic. It is a mistake if our knowledge proceeds from false outcomes. Also conclusions then do not have to be (and mostly are not) valid. Nevertheless, how do we know whether the outcomes are true?

Bacon (similarly to Aristotle) realizes that validity of axioms cannot be proved a priori. Their legitimacy is manifested only from conclusions inferred from them and in a context of other assertions which support validity of given outcomes. Science thus represents a web of mutually reconnected claims which can select erroneous premises thanks to their contradictions. However, they cannot provide a proof that outcomes are really valid. So, if there is a contradiction between outcomes and a certain experience, the experience is determined as invalid or anomalous against the weight of the whole network of assertions which we deduced from the outcome and do not contradict with other experience. Alternatively, we search for other additional axioms or supportive theories which will remove the contradictions or explain it (in astronomy deferents, n–cycles and epicycles). All assertions whose veracity is viewed by us intuitively seem to be equally problematic, as well. Intuition evades control to a considerable extent even, as Bacon implies in his doctrine of the idols, it is frequently distorted (idola tribus, specus, fori).

7.2 Empirical Method

While for scholastic science experience fulfils manly a task of proof, Bacon suggests it to be an outcome of cognition (Bacon, 1990, 136). It is the only way how to avoid devising of (although logically consistent) sciences on defective objects which do not really exist (e.g. "unicornology"). *An observation* will provide us with a contact with reality and our knowledge comes from that. However, Bacon realizes that knowledge is not merely a set of observations. A rational

analysis represents an important task of cognition. Therefore, the observations have to be assessed and the truth has to be inductively "distilled" from them. A task of induction is to find general principles present in nature via the rational analysis of observations. And *a method of table* should serve this purpose.

Bacon's science uses several types of tables, however, the most significant are those which enable us to get to know or exclude incorrect principles. Especially a table of positive instances (Bacon, 1990, 181) and a table of negative instances represent such cases. Bacon knows that substantial features or connections cannot be uncovered on the basis of a single observation. That would be completely intuitional. That is why it is necessary to acquire a sufficient (representative) set of observed instances enabling us to deduce invariants and subsequent forms — general principles from them (Bacon, 1990, 159). The first problem of induction is then multiplicity of observations. It seems the more observations we acquire the more evidently a certainty rises that our generalisation will not be based on random and anomalous observation. It is then optimal to attain observations of all possible instances. However, it is (quite) possible only with minor exceptions because a set of observation objects can be either unlimited or so large that it is not in powers of any human being to perform all relevant observations. The problem of observation of individual objects can be, for instance, that they are not located only within a single limited place (e.g. Britain) but anywhere in the world and moreover, that their occurrence is not time–limited and thus continues regardless of eras (swans in the past, present and all future swans). This fact forces Bacon to think about supranational institutional comprehension of science because it is possible to systematically cover as large sphere of a given research as possible only through a narrow specialisation. However, (as D. Hume pointed out) a crucial problem of the unlimited multiplicity of research objects is that due to incompleteness of a sample we can never be completely sure whether there isn't an element from a given set which has not been observed and which would contradict experience acquired so far. Therefore, the table of negative instances might be even more significant than the table of positive instances. If we find just a single case within it which contradicts experience acquired so far then we have a certainty that the connection of an observed phenomenon, feature or element with the set of objects is not essential but only arbitrary. The table of negative instances thus serves for checking and limitation of possible generalisation arising from the table of positive instances and forms its part. Similarly as a table of prerogative instances (Bacon, 1900, 238), it is a selective and model example of scientific problems solutions (Fischer, 1983, 150).

Other type of example represents a table of degree (Bacon, 1900, 198). Where a causal connection between two variables cannot be clearly determined, certain correlations between their occurrences can be observed and an extent of a mutual connection between two or more factors can be assumed. Bacon does not think about a correlation analysis nonetheless realizes complexity and ambiguity of the relation determined by the extent. Therefore, in order to uncover exact relations among individual researched phenomena as far as possible, it is necessary to find a more pervading research method than a mere observation and it is represented especially by an experiment.

7.3 An Experiment

An Experiment enables us to pervade into the very principles of nature, since we can particularize and purposefully draw our attention to research of specific connections among observed things through gradual exclusion of effects of individual factors. Through checking of variables we force nature to reply to given questions by "yes" or "no". Bacon views the experiment as an examination of nature, "keeping it on tenterhook", and that is why it reveals even the most hidden secrets under pressure of research. If we know how and what to ask, nature reveals its enigmas.

A substantial feature of the experiment represents a need to know where we should look or what to look for. The accumulation of observation itself is not enough, if we do not know what we can see in it. (Columbus did not see America but a western route to India.) Therefore, also filling of columns of individual features or properties is then equally important as filling of lines of multiplicity of observations. If Bacon criticised Aristotle's intuitive uncovering of axioms it should be stated that the mind of a scientist — researcher has to rely just on this vague and almost ungraspable intuitive moment of discovery and invention when generalising or searching for potentially relevant invariants. However, on the contrary to Aristotelianism, validity or invalidity of scientific intuitions can be checked in Bacon's approach at least partially through the table method. Yet, a core of the problem remains — intuitive nature of inductive generalisations and probabilism of cognition arising from incomplete multiplicity but also from potentially incorrectly assumed connections (it can later show that a real cause of a relation represents other (more profound/different) connection than we have assumed). A close connection of observation with an explanatory outcome and thus delusiveness of substance of "raw" observations or observations independent of theories embodies another problem.

7.4 Knowledge for Benefit

A radical change of comprehension of a relation of knowledge to practice represents an essential feature of Bacon's approach. While ancient science embodies knowledge for knowledge, Bacon spreads a thesis "*Knowledge is power*" and emphasizes especially knowledge in the light of nature management.

By uncovering of natural principles we can defend ourselves against undesirable natural effects or produce desirable effects through creation of conditions under which nature will create what we require (Bacon, 1900, 67). A task of science is to help human being reshape their environment according to their needs. A relation of human being and nature thus modified into a pragmatic duel for dominance where knowledge and information become the most crucial weapon.

Bacon became aware of a power character of knowledge and therefore opens a question of possible technological consequence as well as of publicity and privacy of knowledge in his *New Atlantis*. From Platonic character of independence of laws from our knowledge might seem clear that knowledge should be universally available without a possibility to own it. However, from investigative nature of knowledge acquisition follows that its cognition is not for free and its possessing provides its owners with a great advantage of power which they will have only until given knowledge is not generally available.

This fact raises not only a question of a remuneration or benefice, which became characteristic already of universities, but especially a question on unlimited and chargeable or non–chargeable accessibility of knowledge and inventions.

7.5 Recommended Literature

BACON, F.: *The New Organon*. Cambridge : Cambridge University Press, 2000, 33 — 50.

DEAR, P.: The Meaning of Experience. In: LINDBERG, D. C., NUMBERS, R. L. (eds): *The Cambridge History of Science*. Vol. 3. Cambridge University Press 2008, 106 — 132.

BOORSTIN, D., J.: *The Discoverers*. New York : Random house, 1983, 147 — 174.

8. Two Fundamental Modern Times Approaches to Natural Law Discovery

Key words: *discovery, deduction, thought experiment, mathematisation, connection of experience and explanation*

Scientists of modern times became aware of the power and significance of empiricism and also that allocation of observations itself does not necessarily lead to a discovery of generally valid laws. In order to see a principle we do not need only to organise experience but also an ability drawing our attention to vital aspects of a problem. Some discoveries can originate by a mistake or chance; nonetheless a systematic research requires rules. These are provided to us by reason. Without it empiricism would be only a rhapsody of perceptions lacking any order and a foundation.

Early modern science offers us two examples of how reason finds and acquires fundamental principles of world construction. Descartes' search for principles through *(methodical) deduction* and pure reason represents the first one of them (Murray, 2011, 152).

8.1 A Methodological Deduction

Descartes (especially after cooperation with Isaac Beeckman) saw problems connected with Aristotelian explanation of the world, nonetheless assumed that the original explanation needs to be only modified and the terms redefined. Modified yet metaphysical perception of space and place represented an essential outcome of his reasonings. While Aristotelian world was finite, sphere–like and without any possibility of more precise orientation in it (classification into the sublunar and supralunar part and spheres according to presence of the elements), Descartes' space offers very exact orientation within through mathematically expressed coordinates of individual points. Through introduction of Cartesian coordinates he enabled not only analytical description of a place but mainly realized that every single point in space has its unique place, thus infinitely divisible space cannot be separated from corporeity which it is connected with because he comprehends the space as a boundary limited by res extensa. On the contrary to the atomists (especially to Gassendi) he then does not accept existence of atoms and a vacuum but imagines the space as corporeal fullness filled with various types and shapes of matter. Some of the particles are macroscopic and as big as universal bodies, others (filling the sky) are finer than liquids and there are also particles representing the finest matter our mind cannot imagine at all — a light (Gaukroger, 2002, 12 — 13). Descartes' comprehension of corporeal fullness can be compared to rubbing of stones in a liquid. A finer matter (sand), which separates and fills the surrounding space, originates through gradual rubbing of stones. However, there must be even finer environment around the sand and stones which flows around and perfectly fills every single space in the liquid. When comprehending atoms traditionally as the smallest parts of matter, we mostly imagine small spherical objects, yet we overlook that there is a space left among the individual spherical spaces which again has to be filled with something. If there was absolutely nothing in it — a vacuum — it would contradict a potential of motion but also metaphysical comprehension of a space as extensive being. Therefore, Descartes assumes that even this space has to be filled with even finer matter — by elements of the first degree which are so fine that enable complete and perfect filling of any possible vacant places. Descartes' viewing of a space represents a quasi body characteristic of non–homogeneousness and a potential of reorganisation of individual parts. Through this he basically determines

foundations for future formulation of the principle of matter conservation.

Mechanical comprehension of motion represents a vital feature of Cartesian physics. Descartes understands that a cause of motion comes from the first mover. Bodies remain at their place until they are not forced by something to leave it (the first law of motion).

On the contrary to Aristotle, Descartes accepts only rectilinear motion (2nd LM — Descartes 1987, 101 — 102) provided a body is not forced to change such motion. A change of motion, which can be comprehended in two ways, takes place through collisions of bodies. The first way represents a change of direction of motion when a body strikes objects which are more corporeal than itself. In this case motion spreads through a way of minimum resistance which (seems) is smaller in an environment filled with the finest matter particles. Those — contrarily to more corporeal objects which we cannot move but we can rebound from them — we can move by our power. At the same time it is clear that motion of macroscopic bodies will be always accompanied by motion of the finest matter filling their original place. So if any body wants to change its position it can do so only if some other body leaves its place which is, however, possible only if also other bodies leave place for this body. It shows a) a possibility of motion of all parts (making relative motion impossible) or b) a need to admit whirling (relative) motion.

The second aspect of Descartean comprehension of motion is transmission of motion during collisions of bodies. It causes that a moving body gradually transmits its motion to all particles which it collides with. Although the individual particles finally stop, a total sum of motion does not vanish in the universe (3rd LM — the principle of conservation of motion), however only if the universe is enclosed, finite and every single place of it is filled. Descartes views matter as passive although he accepts that motion can be assigned to it secondarily, nonetheless only from an entity whose motion comes from God. Since motion in a completely filled space is always only a contact, it is evident that a total sum of motion will be constant in a given system. Descartes thus created assumptions for comprehension of the universe as perfect perpetum mobile into which God inserted an impulse, and a motion subsequently functions on its own.

Descartes' principle of conservation of motion together with the one on conservation of matter opens a way to remarkable comprehension of a connection of weight and motion speed. Descartes did not notice this relation and believed that less corporeal body cannot move more corporeal one (4th LM). Yet, he realized that a sum of matter, which I should or should not move, represents a crucial factor of motion which enabled him to explain physical phenomena without gravitation. We cannot push away more corporeal objects, however it is questionable, why we cannot jump e.g. to the height of four metres. Descartes assumed that unlimited motion upwards is not possible due to the fact that except for particles of air which surround us we hit also the whole matter of air located above us. We are not drawn by the Earth but we are pushed by the whole matter above us causing that we cannot (similarly as a moon) fly away from the Earth. If there was nothing around the Moon or other planets, they would move away as a stone thrown from a catapult. Matter located above and under them forces them to remain in their orbits.

8.2 A Thought Experiment

Galileo's application of *a thought experiment* embodies the second example of discovering natural laws. One of the fundamental principles of modern science represents comprehension of free fall and discovery of constant acceleration. There are rumours that Galileo discovered it after he performed numerous experiments based on throwing of objects from the Leaning Tower in Pisa. However, he could not discover these principles through experience because experience does not reveal them, even contradicts them since a fall of objects of various sizes from identical height does not indicate

their identical acceleration. This fact can be discovered only in ideal environment — i.e. in environment accessible only to reason.

Galileo meditated on a fall of a sphere and concurrent fall of its hemispheres (Settle, 1967, 319 — 334). As experience shows, heavier bodies fall faster, therefore, it is meaningful to assume lower speed of both hemispheres against the speed of a whole. However, what happens if we bring the hemispheres close to each other? They should still fall slower because they do not constitute a whole. Only when we bind them tightly (e.g. by a long stretched strand) they will create the whole and it should fall faster. However, if the strand tears during a fall, the fall should slow down again. Yet, it is strange to assume different speed of fall of hemispheres brought closely together from the speed of fall of the whole, therefore Galileo concluded that their accelerations are identical and speed is influenced only by resistance of environment depending on the shape of an object. Science of modern times does not look for principles directly among real bodies but discovers a realm of ideal objects and ideal environment through which it researches the common environment. Idealisation is not only an assumption enabling discoveries (acceleration of a falling body is universal and constant, independent of weight) but also a consequence of their discovery and explanation why real bodies do not behave only according to discovered laws (effect of environmental resistance). It is idealisation (of gases, liquids, and environment and also of corporeal objects) and use of thought experiments that enabled discovery of most physical laws of modern times.

A significant feature of Descartes and Galileo's comprehension of science was an assumption that a book of nature is written in a mathematical (geometrical) language (Galileo 1623, 237 — 238). Mathematisation of fyzis (optics, mechanics) stands behind a success of mechanistic science (Husserl, 1972, 43 — 49). Galileo realized that mathematics provides a potential for description of principles through functional equations (Černík et all, 1997, 101) which equipped science with a new type of research as well as a proof.

Similarly to Bacon, Galileo believed in a connection of observation and theory. Legitimacy of science resides in this connection and therefore a scientific proof should rely on both pillars of cognition. Thus, theory explains observations and the observations retrospectively confirm (or contradict) validity of the theory.

While Bacon believed in primariness and intactness of experience, Galileo stressed primariness of explanatory outcomes. No principles can be seen in observations without geometrical and mathematical intuitions (Agassi, 2008, 447). Since mathematics is an axiomatic discipline, also science should be built on axiomatic foundations. What we believe enables us to see what we see.

8.3 Recommended Literature

DESCARTES, R.: *The Principles of Philosophy.* Kessinger Publishing, 2004, 15 — 28.

MELI, D. B.: Mechanics. In: LINDBERG, D. C., NUMBERS, R. L. (eds): *The Cambridge History of Science.* Vol. 3. Cambridge University Press 2008, 634 — 672.

KVASZ, L.: Galilean physics in light of Husserlian phenomenology. *Philosophia Naturalis* Vol. 39 (2002), s. 209–233.

9. Modification of an Astronomical Image of the World

Key words: *geocentrism, heliocentrism, hybrids, magic, ontological status of objects*

9.1 Ancient Times of Astronomy

History of astronomy represents an appropriate example of the connection of theory and observation. The first records of observations of astronomical bodies can be found already around 5,000 BC (The Sumerians — zodiac animals, star observation, a lunar calendar; 4,000 — Egypt — observations Syria, 2,782 — a solar calendar; 2,500 — discovery of cardinal points; 2,400 — China — a planetary conjunction; 2,300 — Babylon — 5 planets (Mercury, Venus, Mars, Jupiter and Saturn), ignis fatuus, the Sun and Moon; 2,000 — China — forecasts of eclipse; 1,900 — Stonehenge; — 1,300 — records of eclipse observations; 1,000 China — determination of the length of the year for 365.25 days; 700 Babylon — time measured with $\Delta t < 1$; 600 — Thales — universal bodies; 500 — Pythagoras — the Earth as a sphere; 400 — Democritus — infinity and void). However, systematic explanation of astronomical phenomena emerges no sooner than with Eudoxus' homocentric system (384 — 322 — Aristotle — an experimental proof of sphericalness of the Earth based on eclipse; 388 — 315 — Heraclitus — rotation of the Earth around its own axis; 320 — 250 — Aristarchus of Samos — heliocentric opinion — mentioned; 240 — Eratosthenes — experimental verification of a semi–diameter of the Earth; 150 — Hipparchus — eccentricity of planet motion + a catalogue of approximately 850 fixed stars + epicycles; 46 BC — Caesar — Julian calendar).

9.2 Ptolemy's Almagest

A philosophical foundation for explanation of knowledge of ancient astronomy represented especially Aristotle's theory of natural places and Ptolemy's theory which was based on it. Around 150 AD in a book Almagest (Great Book), Claudius Ptolemy introduced a model which not only summarised knowledge of his predecessors but mainly created a system enabling explanation of construction of the universe and especially relatively exact predictions of motions of individual planets and celestial bodies through geometrically describable mechanisms. In spite of the fact that with a mounting number of observations it was necessary to make additions and small modifications to Ptolemy's geocentrical system (Alfonso X the Wise — 50 Ptolemaic models of the universe) its predictive power remained unchanged for almost one and a half centuries. So where did the power of Ptolemy's system lie?

High consistency, applicability in a broad spectrum of spheres and persuasiveness of the whole system represented a foundation of Ptolemy's success.

Ptolemy believed that our Earth resides in the centre of the universe because it contains the highest amount of the element of earth. Equally to Aristotle he assumed that it is surrounded by water, air and fire. Except for the geocentrical system, he also inclined to finiteness and sphericalness of the universe. His planetary model assumed a central position of the spherical and motionless Earth with planets Moon, Mercury, Venus, Sun, Mars, Jupiter and Saturn. The universe was terminated by a sphere of fixed stars and the celestial sphere.

In the second book of the thirteen–volume Almagest, he analyses motion of bodies in connection with their rise and set in the sky, terrestrial longitude but also with an equinox and a solstice, and in the third book he uncovers mechanism of motion of the Sun and Hipparchus' problem of precession and the theory of epicycles. He subsequently explains motion of the Moon (book III), Mercury (IX), Venus and Mars (X) and Jupiter and Saturn (XI). He dedicated a special attention to an analysis of seeming retrograde motion of the celestial bodies which he explained through epicycles — a circular trajectory of planets with a centre located on another circular trajectory (deferent) whose centre represented the Earth. Through a suitable choice of semi–diameters of the deferent and epicycle it was possible to determine a position of planets quite precisely that enabled a theoretical model to be identical with observations. With an increasing number of observations the semi–diameters became more precise and if a suitable semi–diameter could not be determined, one of the later solutions was to determine a centre of a deferent outside the Earth which created an eccentric deferent (excenter), or to take into consideration another circle with a mirror image of a position of the Earth (ekvant) with a centre symmetrically removed from the centre of excenter in a distance of the Earth.

A great advantage of Ptolemy's theory was its provision of explanation which *corresponded* with observations which, for a change, corresponded with *predictions*, perfectly fit into a deposit of Aristotelian scientific knowledge, moreover, agreed with natural experience of an individual and found explanation also in self–centred theology. Even in spite of the fact that there were concepts refusing geocentrism during Aristotle's era (Philolaus, Heraclides Ponticus, Aristarchus of Samos) and also authorities that did not believe in motionless and central position of the Earth (Nicholas of Cusa — infinite universe, relativity of motion, rotation of the Earth) in the Church circles.

With an increasing number of observations and making of planet positions more precise, Ptolemy's system required new and new revisions and other complementary constructs and theories (we include also G. Peuerbach and Regiomontan working at

Academia Istropolitana — 1470 among significant astronomers revising Ptolemy). That, however, complicated the system to such an extent that it gradually became indefensible. An effort to simplify the principle of explanation of the world represented the main contribution of Copernicus' theory.

9.3 Copernicus' Turn

Copernicus in his *De revolutionibus orbium coelestium libri* (vol. VI) assumed that it is easier to move the Earth than the whole universe and that a kinematic character and *anti–centricity* of the Earth would provide explanation of visibility of inner planets only in the morning and evening sky. His system reorganises planet positions (the central Sun, Mercury, Venus, Earth (Moon), Mars, Jupiter, Saturn and fixed stars) and does not contradict circularity of orbits and finiteness of the universe (celestial sphere). He determines planet distances through angles remote from themselves in double distance of the Earth from the Sun. Except for radical innovativeness, a problem of his system represented also the fact that it does not correspond with observations of positions of celestial bodies, contradicts common experience and in its own nature is speculative (problem of substantiation of relativity of motion). Therefore, it had not been accepted and substituted by other (*compromise*) alternatives for a long period.

9.4 Hybrid Models

Tycho Brahe's concept embodied one of these alternatives. Having at his disposal excellent and numerous observations (Brahe's quadrant), Brahe assumed that the Earth is a centre of the universe and the Sun and Moon revolve around it. However, all other planets rotate around the Sun. On a basis of comet observations performed by Tadeáš Hájek of Hájek, he replaced solid crystal planet orbits, nonetheless he preserved the fixed stars and celestial sphere.

Giovanni Ricolli, who asserted that the Earth is in a centre of univerzum and the Moon, Sun, Jupiter and Saturn represent planets of the Earth while Mercury, Venus and Mars are planets of the Sun, presents a different alternative. His assignment of Jupiter and Saturn to the planets of the Earth was caused by a relatively short distance of the Earth from the Sun.

In spite of gradual asserting of *helicentricism*, Copernicus' theory did not find general support of scientists due to several reasons. The first one represented its predictive power which was much weaker than Ptolemy's. Impossibility to provide a proof via observation was the second reason. Abolishment of geocentrism itself and its replacement with heliocentrism did not have to cause a problem to a smart theologian (because heliocentrism excellently expresses theocentric nature of theological explanation and there are no proofs of a central or motionless position of the Earth in the Bible except for stopping of the Sun by Josue stressed by Luther (Jos. 10,13)), however his separation from the natural world experienced day by day seems to be the crucial issue. Adherence to the natural world correlates with self–centrism of assumption about a space but also with an opinion that phenomena are the way they seem to us and common experience does not mislead us. Perhaps due to that we still believe in a common language in "rising" of the Sun, Ptolemaic days in a calendar (Monday, Sunday...), etc.

9.5 Assertion of Heliocentrism

We owe especially to Johannes Kepler and Galileo Galilei for prevention of Copernicus' image of the world from Aristarchus' fate.

Kepler in his *Cosmographic Mystery* (1595), in which among others he also dealt with astrology, discovered a system in Copernicus' theory of relations perfectly balanced with a harmony of the world, regularity and perfection of geometrical entities of microcosm (honeycombs, snowflakes, flowers) as well as of macrocosm (as many planets as days), taking into consideration distances, sizes and spacing of planets with the theory of Platonic perfect polyhedrons. During explanation of an astrological theory of a great conjunction of Jupiter and Saturn he realized that through connection of points in the zodiac where the conjunction appears, another inner circle emerges and the ratios between the both circles are very close to distances between Jupiter and Saturn in Copenicus' system (North, 1955, 314). If we at the same time inscribe a cube in Saturn's orbit, we get Jupiter's orbit. Similarly, we can inscribe a tetrahedron between a spherical space of trajectories of Jupiter and Mars, a dodecahedron between Mars and the Earth, an icosahedron between the Earth and Venus and an octahedron between Venus and Mercury.

After he was forced to leave Graz, Kepler accepted Tycho's invitation to Prague where he confronted his Pythagorean enthusiasm with observations. Here, under the influence of plenty of empirical knowledge (*Tabulae Rudolphiniae*) he leaves behind alchemistic and astrologic viewing of astronomy and applies only physical principles for elaboration of his geometrical model of planet motion. Differences between the geometrical model and observations forced him to revise the geometrical model and to harmonize it with physics (Donahue, 2008, 582 — 583). Thus he established a new tradition of astronomy as physical science (*Astronomia nova* — 1609). Kepler discovered that:

1) not circles but ellipses represent planet orbits (it was an intuitive insight because it was impossible to assess effect of Jupiter — in fact, there is no geometrically perfect orbit, only a mechanism of its formation)
2) a speed of a planet changes depending on a connecting line of the planet and Sun which draws an identical area in identical time and
3) square of orbital periods of planets are in an identical ratio as the third powers of major half–axes of respective ellipses.

Thus, through a physical modification of Copernicus' model he created a system which became predictively very effective and not

only clarified the principles of planet motion but also focused on what stands behind them. The orbits and principles are not simple, however, they are formed by simpler principles, and through this fact he slightly opened a door to Newton and a post–Newtonian mathematical and physical research of the universe. Yet, at the same time he separated common experience from the real world.

In less than three month of use of Galilei's telescope (observation of sunspots, Jupiter's moon, and phases of transits of disk of the Sun, "Eppur si muove") empirical knowledge of the celestial bodies changed more than during all the centuries before. Mathematics and physics enabled scientists to speculate about an effect of individual bodies (*Dialogo sopra i due massimi sistemi del mondo; Nuncius siderius)* and to discover them, but also to ponder scientifically on history and future of the bodies. A concept of our system started to be modified, new planets were discovered (Uran — Herschel, 1781; Neptune — Gall, 1846, Pluto — Tombaugh, 1930), nonetheless their status was also subject to change (on June 24, 2006, Pluto was excluded from a set of solar system planets at the 26^{th} General Assembly of The International Astronomical Union in Prague). By the way, history of astronomy is significantly connected just with Prague. According to the legend it was here that Kepler discovered his 1^{st} law of motion on a basis of experience with a ground plan of towers of St. Agnes Church and it was in Prague, too that Tycho Brahe worked.

A significant feature of astronomy is that although it describes real bodies, what it presents is only their *model*. Ptolemaic model of the world was considered correct, although it was not. The universe did not modify through the discovery of Copernicus' concept, yet our whole comprehension of the universe significantly changed. However, thanks to these facts a new question of *ontological nature* of a subject of science itself was opened with new urgency (Bednáriková, 2013). Did "Pluto" exist also before it was discovered or did it cease to be a planet only after astronomers agreed on that?

Is science only *discover*ing of mistakes and adding of the unknown or is it directly constructing of the reality in which we exist? What is a criterion of veracity of knowledge if all scientists believe in it although it later shows as false?

9.6 Recommended Literature

NORTH, J.: The Norton History of Astronomy and Cosmology. New York : 1995, 104 — 124.

DONAHUE, W.: Astronomy. In: LINDBERG, D. C., NUMBERS, R. L. (eds): *The Cambridge History of Science*. Vol. 3. Cambridge University Press, 2008, 562 — 599.

DI LISCIA, D. A., "Johannes Kepler", *The Stanford Encyclopedia of Philosophy* (Summer 2011 Edition), Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/sum2011/entries/kepler/>.

10. Vacuum and Newtonian Physics

Key words: *vacuum, pressure, gravitation, balance, hypothesis*

A similar fate to the one of the refused and forgotten Aristarchus' concept of heliocentrism accompanied plenty of scientific ideas. A concept of a void and a vacuum represented one of them.

In spite of the fact that philosophers had known the void since the times of Leucippus and Democritus, application of this conception into physics was inconceivable for majority of scholars. Plato refused the void due to theological reasons, Aristotle sees infinite speed in absence of a potential of environmental resistance, in his opinion, the void disables natural and imposed motion because it does not enable a contact effect, etc. (Westwick, 2003, 817). The void embodied a logical and metaphysical problem (what is the "void"?) but also threats from a theological background (The void as a manifestation of imperfection of God? his limitation? etc.). Therefore, no wonder, it was rejected and *horror vacui* took place in natural science. Even in spite of that several other aspects of atomism were preserved in modern science also thanks to Epicurus and Lucretius. Descartes accepts some premises of Gassendi's atomic comprehension of matter, nonetheless, similarly to Aristotle (due to impossibility of motion) dismisses the concept of vacuum and fills the space to the last possible area with matter of the smallest possible size. A return of the vacuum to the stage takes place no sooner than in the seventeenth century.

10.1 The Vacuum

Galilei noticed that peasants in the country similarly to workers in mines cannot draw water by suction pumps from a depth greater than 18 cubits (app. 10.5 m; Barrow, 2004, 90 — 111). The problem did not reside in the equipment, since after machines with the highest–performance were used it also did not work, but in water because it is not sufficiently cohesive and a water column breaks. However, what causes the break of the water column?

It seems that the cause lies in impossibility to suck all air or water from an enclosed column. According to Aristotelians, by emptying of a space water should rise and fill an empty space because nature does not allow the void. Yet, in fact, water does not fill the space (is is too heavy?) and the suction pump stops working. Is then the real vacuum not possible? However, why does the given phenomenon take place when the water column is 10.5 m high and not when it is of different height?

Galilei's student Evangelista Torricelli realized that the cause of relative malfunction of the suction pumps represents air pressure or a *difference between pressures* in a column and environment. An interest in a research of (weight of) air is a manifestation of Renaissance and also Nicholas of Cusa focused his attention on that. However, Torricelli became aware of the fact that surrounding air has a certain weight affecting the whole surface of the Earth. The weight of air is caused by pressure and it represents a cause why water cannot be drawn from an enclosed space. Torricelli documented his reasoning by an experiment during which he replaced water (10–metre column) with mercury which is 40–times heavier. He filled a glass test tube with mercury and closed its end with his finger. Then he turned it upside down and sank its opening into a pool (basin) with mercury prepared in advance. When he subsequently freed the test tube opening he noticed that a column of mercury fell nonetheless remained at a height of approximately 76 cm. A reason why all mercury did not leak away and its column

stopped just at this height against a surface of mercury in the basin lay in air pressure on the liquid surface. The fall of the column in the test tube was accompanied by origination of an empty space in its upper part in which there was no matter or air. So Torricelli was able to create the vacuum which not only should not have been possible but, moreover, it was permanently sustainable.

A potential of creation of the vacuum and an opinion that nature is not afraid of it, quite the other way, that it requires it, became a subject of a famous public experiment with Magdeburg hemispheres. Otto von Guericke (1654) proved that if we put together two big bronze hemispheres, connect them hermetically and suck away the air they will be pressed to each other with such a power that it will not be possible to separate them even by a couple of teams of eight horses pulling against each other. However, after loosening of a valve we eliminate the vacuum and the hemispheres will detach themselves.

Aristotelians attempted to prove that a reason why a height of the mercury column does not fall or hemispheres do not separate resides in the suction effect of the vacuum. It prevents gravitation of mercury from falling and keeps it at a certain height via some invisible *funiculus*. So, the vacuum is not absolute, through sucking away of matter there remains a space, laws and similar structures and those prevent the column from changing. Through a series of experiments Robert Boyle tried to prove that the height of the column modifies depending on a change of pressure of surrounding environment (product of pressure and a volume of a given matter amount of an ideal gas is invariable under a constant temperature — Boyl–Mariott's law), yet a finale proof was provided by Blaise Pascal and Florin Périer. Périer implemented Pascal's idea to measure the height of the mercury column next to a sea surface and at high altitude. Via two identical and equally filled tubes (one was left in a base camp, the other taken to the top of a mountain) Périer proved that the height of the mercury column changes depending on altitude i.e. on air pressure which affects its surroundings. With rising pressure (falling altitude) the height of the column falls. This quite well–measurable process depends not only on altitude but also on the weather conditions (air pressure) which is proved be meteorological observations.

10.2 Gravitation

Aristotelian reasonings about cohesiveness and *the suction effect* of the vacuum draw attention to the second significant moment of science of modern times, to an idea of attraction and gravitation. Ancient (and as well Descartes') science comprehended motion as the contact effect in corporeal fullness. Yet, the suction and gravitation assume a certain extent of the vacuum and a contactless action at a distance.

A discovery of *gravitation* principles is assigned to Isaac Newton. However, Newton did not work in vacuum, he knew Galilei' s experiments, Ballialdus or Borelli's works and actively discoursed with Robert Hook who formulated this idea already in 1660 and on the basis of this fact Edmond Haylle accused him of plagiarism (Turnbull, 1960, 431). Elements of Kepler's astronomical conception from which Newton proceeded formed a foundation of Newton's reasoning. Newton realized that the celestial bodies move in Kepler's ellipsoids because they are held there by two essential forces: centrifugal and centripetal. From the centrifugal force he deduced the first law of motion on remaining of a body in repose or rectilinear motion until the body is not forced to change its state already implied by Descartes. Contrarily to Kepler, he also raised a question about causes which do not allow bodies to leave their orbits which led him to formulation of a thesis on the centripetal force. A core of attraction of the centripetal force resides in gravitation of the Earth and it was a concept of general attraction that became central for his physical comprehension.

Scientific philosophers used to and still continue to debate on inspirations which led Newton to the idea of general gravitation

(Harper, 2002, 174). Whatever it was, it was the idea of gravitation which enabled Newton to create an exceptional image of the world in which identical principles are valid for the sublunar and supralunar world. This fact re–opened again a question of its organisation. Newton realised that the world in which corporeal objects act attractively to each other at a distance should collapse to a single point which will represent a resultant of their gravitational forces. Only thanks to a precise balance of placement of bodies in the universe, it is possible that this situation does not take place. The bodies interact and balance themselves and, therefore, none of the planets fall on the Sun because at the same time it is attracted also by all other bodies, inversely proportionally to square of their distances. If we threw only a grain of sand into the universe, this balance would be violated and the universe would break down. In a letter to Richard Bentley he writes that this collapse should inevitably take place in any finite stochastic universe and, therefore, he implies a need of infinite or dynamic view of the universe. It is the centrifugal forces which help that delicate balance thanks to which a harmony found in the universe gets multiplied.

Newton could not imagine achievement of a perfect balance coincidentally or through a gradual development (Kant–Laplace theory), but he did not speculate about sources of this balance, although it is clear that he considered them to be God (Meli, 2008, 668). He likewise did not look for determination of a source and a cause of existence and limited himself only to pronounce that the gravitation (and thus also attraction) is proportional to matter and that this is valid for all corporeal bodies. He assumed that construction of reasonings explaining what stands behind phenomena should not be a part of experimental physics (Newton, 1995, 342).

Newton's *Hypothesis non fingo* became a motto of Newtonian concept of science. Yet, is it really so? Does not formulation of hypotheses, whose validity or invalidity can be proved or refuted, represent a core of a scientific approach? Is not the construction of models, ideations and theories which we apply for description of a state of the world characteristic feature of science? Does science really represent Baconian art of uncovering natural laws from nature itself? If it is so, why do we then know how to formulate a question which brought us to given knowledge?

Newton's methodological purification of science from metaphysical sediments, high precision of predictions created on a basis of his three laws of motion but also thorough mathematisation of natural science celebrated its success through clarity and efficiency. However, Newton's forgetting of metaphysical question only temporarily postponed a return to queries on substance of matter and its properties and it was directly through a concept of a force introduced by Newton.

10.3 Recommended Literature

ILIFFE, R.: Philosophy of science. In: PORTER, R. (ed.): *The Cambridge History of Science: Volume 4, Eighteenth–Century Science*. Cambridge, New York : Cambridge University Press 2003, 267 — 284.

SCHAFFER, S.: Natural Philosophy. In: ROUSSEAU, G. S., PORTER, R. (eds.): *The Ferment of Knowledge. Studies in the historiography of eighteen–century science*. Cambridge : Cambridge University Press, 2008, 55 — 92.

WESTWICK, P.J.: „Vacuum". In: HEILBRON, J. L. (ed.): *The Oxford Compagnion to the History of Modern Science*. Oxford : Oxford University Press 2003, 817 — 819.

11. Matter, Einstein and the Issue of Quantum Mechanics

Key words: *corpuscularity, atom model, energy, quantum physics, Copenhagen interpretation*

11.1 A Corpuscular Theory of Matter

Newton's theory of the general gravitation revived the issue on substance of matter the world is made of. Although Leucippus and Democritus' opinions assuming that substance of matter consists of atoms which cannot be further divided were known, at the same time, for centuries they were perceived only as hypotheses contradicting Aristotelian comprehension of matter in spite of the fact that they were regularly revised and modified by philosophers (Epicurus, Lucretius, Gassendi). An interest in substance of matter can be observed in environment of alchemists (Paracelsus, Helmont), sceptical chemists but also of Descartes and other thinkers. Thanks to Leeuwenhoek and Hook's discovery of a microscope, this interest even increased, nonetheless, only Robert Boyle attempts to formulate the first physical and chemical theory of matter based on an empirical research.

Boyle assumed that basic particles of matter have a potential to change a volume depending on a change of body temperature. Through this conclusion of his deduced from knowledge of essential properties of gases (although the first kinetic theory of gases in which temperature depends directly on an energy of gradual molecule motion was created by Daniel Bernoulli in 1738 — Pišút, Zajac, 2010, 10) he formulated a modern theory of *corpuscularism*. According to this theory, matter consists of small particles "characteristic of extension, hardness, impenetrability, mobility and inertia", and also Newton assumed the same (Newton, London, 1686).

Without doubt, corpuscular explanation of matter was the most common, nonetheless, a different concept from Rudjero Josip Boškovič, M. Michell and finally also from Joseph Priestly emerges shortly after Newton's death (Schaffer, 2008, 64). They all assumed that corpuscularity of matter is not a substantial reason for its solidity. It is the centrifugal and centripetal forces that represent it. Thus, similarly as Leibniz and Kant, they open a way to the beginnings of noncorpuscular comprehension of matter. Yet, this way of explanation of matter remained in the background.

The main stream of theories of matter was corpuscularly based. After a discovery of the principle of conservation of matter (Antoine Lavoisière) and the law of constant proportions, John Dalton comes with the first theory of matter consisting of different types of atoms (*A New System of Chemical Philosophy*, 1808). Dalton proved different atomic weight of six types of atoms (H, C, O, S, N) and believed that all properties of individual substances can be explained through properties of their basic elements — all atoms of the same element are identical. Atoms of different elements are dissimilar. An assumption that individual substances are composed of different types of atoms represented a vital feature of Dalton' s theory. Compounds are simple and mathematically expressible combinations of atoms and therefore it is necessary to analyse properties of elements as such. Mendeleev's table of elements mapping characteristics of atoms of individual elements represents its continuation.

11.2 Atom Models

Dalton's theory mathematised chemistry but also brought a lot of controversies partially also due to incorrect assumptions of Dalton

(water as HO). Therefore, Sir Benjamin Collin Brodie formulated an antiatomic mathematical theory (*Calculus of Chemical Operations,* 1866*)* and even Ernst Mach opposed atomistic comprehension of matter at the beginning of the 20^{th} century. A discovery of sub–elementary particles represented a significant breakthrough in explanation of the theory of matter. In 1897, J. J. Thomson discovered that during experiments with a cathode ray extremely small negative particles emerged which were later named electrons. Thompson realised that due to their light weight and negative charge they must represent atom particles and that fact led him to postulate an atom model termed *Plum Pudding Model*. Thompson assumed that there are negative particles in relatively positively charged mass and through that figuratively destroyed (alleged) inseparability of Democritus' atom.

After a discovery of an atomic core, Ernst Rutherford comes with different — *planetary atom model* assuming existence of a positively charged particle in the very centre of an atom and revolving of an electron in external orbits. Niels Bohr revises this model and formulates a model with dissimilar valence layers representing a forerunner of a quantum atom model.

At first sight it might seem that history of atom represents only discovering of individual sub–elementary particles which fulfil function of the original atom of Leucippus. As if a neutron, boson and graviton should replace structures which cannot be further divided. Yet, the reality is more complicated.

11.3 Matter as Energy

Albert Einstein, who through his study on Brownian motion confirmed Dalton's atomic theory, proved that light of appropriate wavelength emits (ejects) electrons from a surface of a metal or a semiconductor on which it falls. Through this fact he explained a photoelectric phenomenon (for which he was awarded the Nobel Prize in Physics in 1921), but also pointed out to a connection of energy with weight because energy of falling radiation changes into kinetic energy of an electron and subsequently through it, it overcomes forces binding it to matter. At the same time when these electrons are being emitted, energy equal to a difference of weight before and after decomposition of an atom is released.

Einstein united the principle of conservation of energy already assumed by Leibnitz with the principle of conservation of weight (Lomonosov, Lavoisier) and proved that matter can be reduced into energy. Einstein proved that energy equal to product of weight of modified matter and speed of light squared can be released from any amount of matter under optimum conditions (determined by him). Thus, there (again) emerged a concept that matter consists of extremely cumulated energy and that is why it can be reduced to it.

Other example of Einsteinian "contradiction" of Newton's physics represents his comprehension of time and space. Einstein proved that Newtonian homogenous and ubiquitous space and time are not an inert world scene, nonetheless, a manifestation of matter and energy and are also curved according to their extent of occurrence. Moreover, they are rather relative than absolute towards a frame of reference and its speed. The special theory of relativity thus modifies a view on absoluteness of events all over the world (description of all events is relative regarding the frame of reference towards which it is described), although physical laws are absolutely valid in a system. Constant speed of light in the vacuum, which as Einstein assumes is not a subject to Newtonian velocity composition and represents a limit to any possible speed of causal connections, embodies one of the reasons. And it is nature of light that connects Einstein with another physical approach — the quantum mechanics.

11.4 Quantum Physics

Proceeding from Planck's hypothesis Einstein in his reasonings on the photoelectric phenomenon postulated an idea that electromagnetic radiation spreads in quanta (Einstein, 1905, 132 — 148).

These quanta are called photons. On the basis of this knowledge Niels Bohr created his quantum atom model and together with Werner Heisenberg deduced knowledge claiming that light has particle as well as wave nature — Luis de Broglie formulated wave properties for all corporeal particles (Broglie, 1925). *Complementarity* — a consequence of this knowledge corresponds with the special theory of relativity yet causes problems for classical comprehension of a relation of a physical phenomenon and its independence of observation. According to the Copenhagen interpretation, the nature of observed phenomenon depends on the way we observe it. An object is also constituted by the observation method (instrument set) which leads to several logical paradoxes

(Schrödinger's cat, Wigner's friends, the Einstein–Podolsky–Rosenov paradox). Moreover, our cognition is in principle probabilistic because it is not possible to know a value of all properties of a system at the same time (Laplace's demon) and properties which are not known precisely have to be described probabilistically (Heisenberg's uncertainty principle).

The theories of quantum physics enabled relatively precise explanation of plenty of phenomena of physical reality, however, they cannot be always used also for explanation of macroscopic phenomena. Moreover, some principles of the quantum mechanics cannot be synchronised with the general theory of relativity. That is why physicists expect formulation of more general and unifying theory of everything. The string theory embodies one of the possible candidates of such a theory. It assumes that a basis of matter does not constitute of dimensionless particles but one–dimensional vibrating *strings*. Thus, behaviour of particles can be explained through connection and disconnection of strings and their oscillation. A problem of this theory resides in the fact the strings as well as additional dimensions of 11–dimensional universe in the sting M–theory are so small that they are (some dimensions are already basically) nonobservable. This fact (together with the Copenhagen interpretation) returns us to the question of epistemic requirements and an ontological status of a scientific object.

11.5 Recommended Literature

DARRIGOL, O.: Quantum Theory and Atomic Structure, 1900 — 1927. In: NYE, M. J. (ed.): *The Cambridge History of Science: Volume 5, The Modern Physical and Mathematical Sciences*. Cambridge, New York : Cambridge university Press 2003, 331 — 349.

EINSTEIN, A.: *Out of My Laters Years*. New York : Open Road, 2011, 41 — 104.

HAWKING, S.: *The Universe in a Nutshell*. Bantam Books : New York, 2001, 29 — 65.

12. History of Science as Modification in the Image of the World

Key words: *cumulativism, anticumulativism, paradigm, (in)commensurability, methodological anarchism*

12.1 Science as Knowledge Growth

The discussion of physicists on compatibility of Newtonian physics and Einstein's image of the world (is classical mechanics valid only as a restricted example (for low speeds) of the theory of relativity or does it represent a completely different concept?) opens a fundamental question about nature of science and scientific cognition.

A lot of philosophers believed in gradual purification and specification of scientific knowledge against religious and philosophical image of the world (Comte) as well as in the process of scientific cognition development itself. Positivists thought that over time we would be able to formulate precise and accurate assertions about the world corresponding to facts observable by scientific methods, and through development and improvement of methods such assertions would permanently emerge similarly as plenty of scientific specialisations and their fields. Thus, they viewed science especially as a constantly developing cognition (like rings on a surface after a stone is thrown into water) and our task was to find a universal language to be able to formulate all principles and synthesize knowledge.

The problem of the neo–positivist perspective on science represented not only a *verification* method but also the ontological status of facts as scientific knowledge itself. The representatives of the Vienna Circle believed that what scientific assertions claim are facts independent of a subject and a method of observation. They assumed that the subject of science represents only true propositions whose veracity is derived from a formal structure of a proposition itself (sentence, mathematics, logic, etc.), or atomic propositions (logical atomism) corresponding to reality as such, to raw observations — protocol propositions. The subject of scientific cognition of the world should embody pure observations of facts — acquisition of sensory data and exact statement about them. Thus they came to the verification method (a proof points out to verity) as the only real criterion proving veracity of scientific propositions. Yet, Karl Raimund Popper pointed out that the requirement of verification is basically unfulfillable.

12.2 Science as Disproving of Errors

From nature of inductive cognition follows that validity of generalisations deduced from empirical experience cannot be proved but only empirically tested. The reason lies mainly in incompleteness of all possible observations (in future there may appear observation contradicting the generalisation) but also in a possibility of principled erroneousness of our cognition (the Duhem–Quinn thesis on indeterminacy of theory by empirical evidence asserts that observations does not unequivocally lead only to a single valid generalisation) — in falibillism. Therefore, Popper suggests replacing of verification with *falsification* — disproving of assertions which are evidently erroneous. Preference of Baconian table of negative instances uncovers a change in comprehension of ontological nature of the scientific subject and science itself.

Popper realised that the subject of science represents not only observations but especially our hypotheses on facts. The hypotheses are our products and that is why it is not possible to prove their concord with the world independent of us. Moreover, individual observations cannot prove inevitable validity of general assertions (problem of induction) but on the other hand, only their potential invalidity. Therefore, for Popper a scientific assertion is only an assertion whose invalidity can be verified through principles (to falsify) and is not self–confirming (psychoanalysis, theory of class enemy ...). Assertions which stood the process of falsification until nowadays are not necessarily true but have not been falsified so far which might mean that they can be disproved in the future. However, the more ways of principled falsification there are, the better, if an assertion keeps holding out in them — there is a possibility that it is true. Popper's concept of science is then opposite. The subject of science represents gradual exclusion of incorrect and erroneous assumptions — approaching the truth through elimination of errors.

12.3 Science as a Narrative System

The members of the Vienna Circle as well as Popper assume more or less ahistorical *cumulativistic* or *anticumulativistic* comprehension of science. Thomas Samuel Kuhn redefines this approach and assumes that the subject of scientific research does not represent a fact independent of observation, nonetheless a product of a concrete scientific paradigm. Kuhn became aware of inseparability of observation from interpretation and in his *Structure of Scientific Revolutions* points out to a moment of object construction through his explanatory outcomes. Thus, he views science as a change of gestalt where what we see is determined by an overall scientific explanation and a sum of accepted solution formulas — paradigm — although a concept of paradigm itself is very non–homogenous (Kuhn uses it in 22 meanings even in *The Structure of Scientific Revolutions*, therefore, he later modifies it into a concept of a disciplinary matrix (Kvasz, 1997, 32 — 37). It follows that Aristotle did not perceive identical phenomena to Galileo or Einstein, each of them observed different phenomena in dissimilar contexts. Kuhn's holistic comprehension assumes certain incommensurability of scientific paradigms as dissimilar means of viewing and explanation of the world. What can be observed is only a potential of a new paradigm to define problems of older explanation and to compose them into the new one. Pieces of anomalous experience play a substantial part in it. In the old paradigm, they represent observations contradicting a generally deep–rooted solution formula. However, if there are just few of them or they are not substantial, a scientific community questions them and pushes them to a periphery. Yet, if plenty of them accumulate or they deal with a substantial part of scientific explanation, they motivate to search for a new approach including anomalous experience into normal science. Thus, the old anomalous paradigm becomes a core explanation of the new paradigm. That is why the new paradigm explains more, yet in a different way. Kuhn was predominantly interested in a way how a change of paradigm (of discovery) and attitudes in a scientific community takes place, and pointed out to principled interpretativeness of scientific theories.

12.4 A Contest of Scientific Theories

Imre Lakatos — another student of Popper's — realised that it is especially epiphenomenal assertions that continuously modifies in science. In his diachronic approach to science he distinguishes individual paradigms as scientific research programmes (SRP) and what differentiates them is mainly a network of their core propositions. It consists of a set of firm core assumptions and assertions — "hard core" — and all empirical claims and observed facts arise from them. These claims and facts can be found on a periphery and come from the hard core, support it and fulfil correctness of its assumptions. The empirical periphery thus fulfils a function of negative and positive heuristics. The negative heuristics does not enable us to falsify programme core propositions (means through which we would like to falsify is inadmissible in a given

scientific programme) while the positive heuristics enables a system to assume what is possible to observe in a scientific research programme.

Observation of preciseness of solution algorithms from one scientific discipline or SRP to another represents an interesting topic of history of science. An excellent example of such use of a positive heuristic potential is the application of physicalistic concepts, theories and procedures in other disciplines, for instance, in chemistry or psychology. Mechanistic comprehension of the world can be seen in modern mechanistic comprehension of human being, for instance, by philosophers of French Enlightenment but also in Freud's psychoanalysis. He used a potential of Pascal's comprehension of hydrostatics and applied it to his theory of unconsciousness. Emotionally charged experience affects consciousness, if its effect is inadmissible for an individual, he attempts to push it into unconsciousness. However, owing to laws of hydrostatics, the unconscious mental object once again affects consciousness of the individual, what frequently manifests in neuroses and obsessions. Hydrostatic terminology documents "resistance" and several other concepts of Freud. A similar example represents application of biologism in the 19th century — Darwin's evolutionary explanation in non–biological spheres — for instance in social sphere (or influence of Herbert Spencer on Darwin; compare: Sedláček, 2012, 275) or on explanation of development of cognition itself (evolutionary epistemology, Popper's theory of science, social neo–Darwinism — meme theory). Application of game theory which originally represented an economical model is another example. Although it did not prove to be very successful in economics, in social neo–Darwinism, it effectively explains such complicated phenomena as altruism, pro–social behaviour or explanation of attractiveness (Démuth, 2013). Thus, the hard core of SRP can be very productive also in other scientific disciplines and after application in the home discipline (even if it was unsuccessful) can cause significant development of other scientific disciplines.

Lakatos points out to a contest of SRP taking place through their positive heuristics. Owing to the fact that the cores are incommensurable, we can compare only what SRP enables us to observe. If a programme ceases to assume facts, probably, it will be necessary to reconstruct the whole core — history of science as a process of rational reconstruction of SRP. Therefore, Paul Karl Feyerabend came to a conclusion that the most progressive method how to acquire as high amount of pieces of knowledge as possible is not to follow only a single methodological procedure but to test as many of them as possible and also even those which a given SRP does not offer. Although a proposition "Anything goes" (Feyerabend, 2002) leads to methodological anarchism, at the same time it implies that no SRP is a priori more correct than the other, if we do not take into consideration what enables us to explain and practically realise.

However, it applies also to science. Feyerabend does not comprehend science as the only correct approach clarifying nature of the world but as one of many, although it is undoubtedly very effective. Cognition (and thus also scientific one) is nothing else than an effort to find and keep finding the best interpretations which observation offers.

12.5 Recommended Literature

KUHN, T. S.: *The Structure of Scientific Revolution*. Chicago : The Chicago University Press, 2012, 111 — 134.

FEYERABEND, P.: *Against Method*. London, New York : Verso, 2002, 14 — 23.

LAKATOS, I.: History of Science and Its Rational Reconstruction. *Proceedings of the Biennal Meeting of the Philosophy of Science Association*, Vol. 1970 (1970), 91 — 136.

References

AGASSI, J. *Science and its History*. Boston: Springer, 2008.

ASHWORTH, E. JENNIFER, "Medieval Theories of Analogy", *The Stanford Encyclopedia of Philosophy* (Fall 2009 Edition), Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/fall2009/entries/analogy–medieval/>.

ARISTOTLE: *Posterior Analytics*. CreateSpace Independent Publishing Platform, 2012.

ARISTOTLE: *Physics*. Oxford University Press, 2008.

ARMSTRONG, K.: *Dejiny mýtov*. Bratislava : Slovart, 2005.

BACON, F.: *The New Organon*. Cambridge : Cambridge University Press, 2000.

BACON, F.: Novum Organon. In: SPEDDING, J., ELLIS, R. L., HEATH, D. D. (eds.): *The Works of Francis Bacon by Francis Bacon.*. Vol. VIII. Boston : Houghton, Mifflin and company, 1900.

BARNES, J.: Aristotle. In: TAYLOR, C.C.W., HARE, R. M., BARNES, J., THOMAS, K.: *Greek Philosophers: Socrates, Plato, Aristotle (Past Masters)*. Oxford : Oxford Paperbacks, 2001.

BARNES, J.: Aristotle's theory of demonstration", in *Phronesis* 14, 1969, 123 — 152.

BARROW, J. D.: *Teorie ničeho*. Praha: Mladá fronta, 2004.

BEDNÁRIKOVÁ, M.: *Úvod do metodológie vied*. Trnava : FF TU, 2013.

BINMORE, K.: *Game Theory and the Social Contract I*. Cambridge : MIT Press, 1994.

BINMORE, K.: *Game Theory and the Social Contract II*. Cambridge : MIT Press, 1998.

BOORSTIN, D., J.: *The Discoverers. A History of Man's Search to Know His World and Himself*. New York : Random house, 1983.

BURIDAN, J.: The Impetus Theory of Projectile Motion. In: GRANT, R. (ed.): *A source book in medieval science*. Harvard University Press, 1974, s. 275–279.

BURKERT, W.: *Lore and Science in Ancient Pythagoreanism*. Harvard University Press, 1972.

CAMPBELL, J.: *The Power of Myth*. New York : Doubleday, 1988.

CASSIRER, E.: *Essay on Man*. Yale University Press, 1977.

ČERNÍK, V., VICENÍK, J., VIŠŇOVSKÝ, E.: *Historické typy racionality*. Bratislava : Iris, 1997.

DARRIGOL, O.: Quantum Theory and Atomic Structure, 1900 — 1927. In: NYE, M. J. (ed.): *The Cambridge History of Science: Volume 5, The Modern Physical and Mathematical Sciences*. Cambridge, New York : Cambridge university Press, 2003, 331 — 349.

DE BROGLIE, L.: Ann. Phys. (Paris) 3, 22 (1925).

DE BROGLIE, L.: *Recherches sur la théorie des quanta*, Thesis (Paris), 1924;

DEAR, P.: The Meaning of Experience. In: LINDBERG, D.C., NUMBERS, R.L. (eds): *The Cambridge History of Science*. Vol. 3. Cambridge University Press, 2008, 106 — 132.

DESCARTES, R.: *The Principles of Philosophy*. Kessinger Publishing, 2004.

DI LISCIA, D. A., "Johannes Kepler", *The Stanford Encyclopedia of Philosophy* (Summer 2011 Edition), Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/sum2011/entries/kepler/>.

DIOGENÉS LAERTIOS: *Životy, názory a výroky proslulých filosofů*. Pelhřimov : Nová tiskárna, 1995.

DONAHUE, W.: Astronomy. In: LINDBERG, D. C., NUMBERS, R. L. (eds): *The Cambridge History of Science*. Vol. 3. Cambridge University Press, 2008, 562 — 599.

EINSTEIN, A.: Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt, *Annalen der Physik* 17 (1905) 132 — 148.

EINSTEIN, A.: *Out of My Laters Years*. New York : Open Road, 2011.

ELIADE, M.: *Myth and Reality*. New York : Harper & Row, 1963.

EUKLID: *Elementes*. Green Lion Press, 2002.

EWANS, J. ST. B. T.: The influence of prior belief on scientific thinking. In: CARRUTHERS, P., STICH, S., SIEGAL, M.: *The cognitive basis of science*. Cambridge University Press, 2002, 193 — 210.

FERGUSON, K,: Pythagoras: *His Lives and the Legacy of a Rational Universe*. London : Icon Books, 2011.

FEYERABEND, P.: *Against Method*. London, New York : Verso, 2002.

FLOSS, P.: *Proměny vědení*. Praha : Mladá fronta, 1987.

GALILEI, G.: *The Assayer*. In: DRAKE, S.: *Discoveries and opinions of Galileo*., New York : Doubleday Company, 1957, 229 — 280.

GAUKROGER, S.: *Descartes' System of Natural Philosophy*. Cambridge : Cambridge University Press, 2002.

GRANT, E.: *The Nature of Natural Philosophy in the Late Middle Ages (Studies in Philosophy and the History of Philosophy, Volume 52)*, CAU Press, 2010.

GRANT, R.: Isidore of Sevile: On the Quadrivium, or Four Mathemathical Sciences. In: GRANT, R. (ed.): *A source book in medieval science*. Harvard University Press, 1974, 3 — 16.

HAKINSON, R.I.: Science In: Barnes, J. (ed): *The Cambridge Companion to Aristotle*. Cambridge: Cambridge University Press, 1995, 140 — 168.

HARE, R. M: Plato. In: TAYLOR, C.C.W., HARE, R. M., BARNES, J., THOMAS, K.: *Greek Philosophers: Socrates, Plato, Aristotle (Past Masters)*. Oxford : Oxford Paperbacks, 2001, 133 — 190.

HARPER, W.: Newton's argument for universal gravitation. In: COHEN, I. B., SMITH, G. E. (eds.): *The Cambridge Compagnion to Newton*. Cambridge University Press, 2002.

HAWKING, S.: *The Universe in a Nutshell*. Bantam Books : New York, 2001.

HONKO, L.: *The Problem of Defining Myth*. In: DUNDES. A. (ed.): *Sacred Narrative: Readings in the Theory of Myth*. Berkeley : University of California Press, 1984, 41 — 52.

HUFFMAN, C. A.: The Pythagorean Tradition, in *The Cambridge Companion to Early Greek Philosophy*, A. A. Long (ed.), Cambridge: Cambridge University Press, 1999.

HUSSERL, E.: *Krize evropských věd a transcendentální fenomenologie*. Praha : Academie, 1972.

ILIFFE, R.: Philosophy of science. In: PORTER, R. (ed.): *The Cambridge History of Science: Volume 4, Eighteenth–Century Science*. Cambridge, New York : Cambridge University Press, 2003, 267 — 284.

IRWIN, T.: *Aristotle's First Principles*. Oxford : Clarendon Press, 1988.

JUNG, C. G.: *Výbor z díla IV — Obraz člověka a obraz Boha*. Praha : Nakladatelství Tomáše Janečka, 2001.

KAHN, CH. H: *Pythagoras and the Pythagoreans: A Brief History*. Indianapolis : Hackett, 2001.

KAPLAN, R., KAPLAN, E.: *Hidden Harmonies: The Lives and Times of the Pythagorean Theorem*. New York : Bloomsbury Publishing USA, 2011.

KARAMANIDES, D.: *Pythagoras: Pioneering Mathematician And Musical Theorist of Ancient Greece*. New York : The Rosen Publishing Group, 2006.

KRATOCHVÍL, Z.: *Mýtus, filosofie a věda I a II*. Praha : Michal Jůza & Eva Jůzová, 1996.

KUHN, T. S.: *The Structure of Scientific Revolution*. Chicago : The Chicago University Press, 2012.

KVASZ, L.: Kuhnova štruktúra vedeckých revolúcií — ako ďalej. In. *Kritika a kontext*. 1997/4, 32 — 37.

KVASZ, L.: Galilean physics in light of Husserlian phenomenology. *Philosophia Naturalis* Vol. 39 (2002), s. 209–233.

LAKATOS, I.: History of Science and Its Rational Reconstruction. *Proceedings of the Biennal Meeting of the Philosophy of Science Association*, Vol. 1970 (1970), 91 — 136.

LE GOFF: *Intellctuals in Middle Ages*. Blackwell, 1993.

LEINSLE, G.U.: *Introduction to Scholastic Theology*. Catholic University of America Press, 2010.

LÉVI–STRAUSS, C: *Structural Anthropology.* Basic Books, 1974.
LEWES, G.M.: *Aristotle: Chapter from the History of Philoosophy.* London: 1864.
LIVIO, M.: *The Golden Ratio.* New York, Brodway Books, 2003.
MELI, D. B.: Mechanics. In: LINDBERG, D. C., NUMBERS, R. L. (eds): *The Cambridge History of Science*. Vol. 3. Cambridge University Press, 2008, 634 — 672.
MURRAY, M.: Descarteś Method. In: BROUGHTON, J., CARRIERO, J. (eds.): *A Companion to Descartes*. Oxford : John Wiley & Sons 2011, 145 — 163.
NEWTON, I.: General Scholium. In: COHEN, I.B., WESTFALL, R. (eds.): *Newton: Texts, Background and Commentaries*. New York : W.W. Norton 1995, 339 — 342.
NEWTON, I.: Philosophiae naturalis principia mathematica, London, 1686. Citované podľa nemeckého vydania „*Sir Isaac Newton's Mathematische Principien der Naturlehre*", ed. J. Wolfers, Verlag R. von Oppenheim, Berlin 1872.
NORTH, J.: *The Norton History of Astronomy and Cosmology*. New York : 1995.
PIAGET, J., GARCIA, R.: *Psychogenesis and History of Science*. New York : 1989.
PIŠÚT, J. ZAJAC, R.: *Kniha o atómoch a kvantovaní.* Bratislava : Knižničné a edičné centrum FMFI UK, 2010.
PLATO: *Republic*. Basic Books, 1991.
POPPER, K.R.: *Hľadanie lepšieho sveta*. Bratislava : Archa, 1995.
ROSENBERG, A.: *Philosophy of Science. A Contemporary Introduction*. London — New York : Routledge, 2000.
SCHAFFER, S.: Natural Philosophy. In: ROUSSEAU, G. S., PORTER, R. (eds.): *The Ferment of Knowledge. Studies in the historiography of eighteen–century science*. Cambridge : Cambridge University Press, 2008, 55 — 92.
SEDLÁČEK, T.: *Ekonomie dobra a zla*. Praha : 65. pole, 2012.
SENTIVÁNI, M.: Sústava sveta. Kozmologická štúdia. In: *Slavica Slovaca*. Roč. 46, rok 2011, č. 3. Supplementum. Dostupné na http://slavu.sav.sk/casopisy/slavica/2011_03/2011_3.pdf
SETTLE, T.: Galileo's use of experiment as a tool of investigation. In: MCMULLIN, E. (ed.): *Galileo, Man of Science*, New York : Basic Books Publishers, 1967, 315 — 337.
SMITH, R.: Aristotle's Theory of demonstration. In: ANAGNOSTOPOULOS, G. (ed.): *A Companion To Aristotle*. Willey–Blackwell, 2099, 51 — 65.
SPENGER, I., INSTITORIS, H.: *The Malleus Maleficarum.* New York : Cosimo, 1997.
SPINOZA, B.: *Tractatus theologico–politicus*. Leiden : Brill Paperbacks, 1991.
TAIT, W.W.: Noesis: Plato on exact science. In: MALAMENT, D.: (ed.) *Reading Natural Philosophy: Essays in the History and Philosophy of Science and Mathematics to Honor Howard Stein on His 70th Birthday* . Chicago and La Salle : Open Court, 2002.
TALEB, N.N.: *Černá labuť*. Praha : Paseka, 2011.
TATON, R.: *Ancient and Medieval Science. From Prehistory to AD 1450*, London : Thames and Hudson, 1957.

TURNBULL, H.W. (ed.): *Corespondence of Isaac Newton*, Vol. 2 (1676–1687), Cambridge University Press, 1960.
VIGNOLI, T.: *Myth and Science*. The Echo Library, 2007.
VON FRITZ, K.: The Discovery of Incommesurability of Hippassus of Metapontum, *Annals of Mathematics*, 1945, 46, 242 — 264.
VOPĚNKA, P.: *Meditace o základech vědy*. Praha : Práh, 2001.
VOPĚNKA, P.: *Úhelný kámen evropské vzdělanosti a moci*. Praha: Práh, 2000.
WESTWICK, P.J.: Heslo „Vacuum". In: Heilbron, J.L. (ed.): *The Oxford Compagnion to the History of Modern Science.* Oxford: Oxford University Press 2003.
WHITEHEAD, A.N.: *Science and the Modern World*. New York : The MacMillan Company, 1925.
WILDBERG, CH.: *John Philoponus' Criticism of Aristotle's Theory of Aether.* Berlin : Walter Gruyter, 1988.

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