МИНИСТЕРСТВО ОБРАЗОВАНИЯ И НАУКИ РОССИЙСКОЙ ФЕДЕРАЦИИ

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Философские проблемы естествознания

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В настоящем пособии изложены учебно-методические материалы по курсу “Философские проблемы естествознания” для иностранных студентов, обучающихся в ННГУ по направлению подготовки 38.04.02 «Биология» (магистратура).

Учебно-методическое пособие предназначено для студентов факультета иностранных студентов, обучающихся по направлению подготовки 38.04.02 «Биология» и может быть использовано как для работы в аудитории, так и для самостоятельной работы.

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Philosophical problems of Natural Science

Tutorial

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Unit 1. Science, its origin and development

It is surprisingly difficult to arrive at a precise definition of science [Lindberg 2010: p.1], given the fact that it is a complex socio-cultural and historical phenomenon. The nature of science has been the subject of vigorous debate for centuries – a debate conducted by scientists, philosophers, historians, theologians, and other interested parties. No general consensus has been reached; however, several conceptions of science have gained most support. Science in its main domains acts as: (1) organized, systematic, and reliable knowledge on different spheres of reality; (2) an intellectual and practical activity of producing such knowledge; (3) a social institute.

Taken broadly as a special way of pursuing knowledge, science originally formed an integral part of philosophy or, to be exact, **natural philosophy**. Moreover, its earliest forms have been traced to the period before the modern era, up to prehistoric or preliterate human societies with their first efforts to understand the physical world in their struggle to survive. People observed and accumulated practical knowledge about the behavior of animals and the usefulness of plants as food and medicine; and then they passed it down from generation to generation. They perhaps picked out knowledge about nature from hunting and the earliest kinds of agriculture [Lindberg 2010: p.4-5].

A more formalized inquiry and the first written evidence of it appeared around 3,500 to 3,000 BCE in Mesopotamia and Ancient Egypt. Both civilizations represent practical interests primarily in astronomy, mathematics, and medicine, however, with a great emphasis on magic, mythology, and religion as the means of explaining the creation of the world and its operations. Egyptians and Mesopotamians viewed the world as a place where magic was essential for survival. It was used to explain virtually all phenomena that we would regard as natural. In those civilizations "religion, myth, magic, and gross observation fused together to provide a variety of answers to puzzling questions" [Grant, 2007: p. 2]. Their cosmogony, or a conception about the origins of cosmos, had a divine nature. The Egyptians, for example, assumed that the world had been created out of Nun, the primordial watery abyss, out of which things emerged, including gods. The diagnosis and treatment of internal ailments in Ancient Egypt relied on magic and were believed to be caused by the presence of demons in the body. Both Egyptian and Mesopotamian medics recited spells and incantations to drive the demon from the body and used amulets for protection. Along with it, Egyptian physicians used drugs and medicine for which they acquired a reputation in the ancient world [Grant, 2007: p. 2-3; Lindberg 2010: p. 8-9].

In both civilizations, great achievements were made in astronomy. Around 2900 BCE, Egyptians devised a civil calendar of exactly 365 days. It was, however, Mesopotamians who brought astronomy to its greatest heights in the period around

500 BCE, being able to utilize an exceptionally well-developed mathematics [Grant, 2007: p. 4-5]. A tradition of pre-scientific inquiry also emerged in Ancient China where physical world was explored using some metaphysical principles such as the yin and yang, as well as the five phases of fire, earth, metal, wood and water to describe a cycle of transformations in nature. Ancient Indian cultures left us a conception of the universe as constantly being recycled and reformed. Health and illness are seen here as the combination of three humors – wind, bile and phlegm – the balance between them is needed for a healthy life [Magner, 2002: p. 4, 6].

A very important turning point was the development of natural philosophy in Ancient Greece that invented the concept of *physis*, "nature", which embraces natural things as opposed to artifacts (*techne*, "craft" or "art"). It is considered to start from the activity of the first Greek thinkers such as were Thales, Anaximander, Pythagoras, Xenophanes, Heraclitus, Democritus and others (6th and 5th century BCE). They were called *physiologoi* ("physical or natural philosophers). They rejected traditional mythological explanations in favor of more **rational natural explanations of the world**. The philosophers from Miletus held that all natural phenomena are manifestations of a single underlying substance or force: water for Thales, nous for Anaxagoras (a ruling principle or aim for things), etc. Democritus is known for the conception that the world consists of atoms – tiny, invisible primary bodies moving through the infinite void; the assumption which as atomic theory entered the scientific mainstream in the early 19th century, due to discoveries in chemistry [Grant, 2007: p. 14-15].

The Greeks were also skilled in mathematics, especially geometry. The earliest records of geometry can be traced to ancient Mesopotamia and Egypt; however, that early geometry originated to meet practical needs in construction, astronomy, crafts, etc. The fundamentals of pure geometry were set down by the Greek mathematician Euclid in his *Elements*, which provided the model of deductive reasoning from self-evident axioms or postulates, step-by-step. The towering figure in Ancient Greek philosophy was **Aristotle** (384-322 BCE), who contributed to logic, metaphysics, mathematics, physics, biology, botany, ethics, politics, medicine, etc. He radically transformed most, if not all, areas of knowledge he touched. Aristotle developed a formalized system of logic reasoning. He also gave special importance to experience and careful study of the natural world. However, in his view, philosophy is the main knowledge, and other sciences cannot contradict it. Aristotle's authority in many philosophical and in most scientific issues remained dominating up to the modern era, which began approximately in the 16th century [Shields, 2015].

The origin of science in its modern usage is considered to take place in the 16th and 17th centuries. To be exact, **Galileo Galilei** is "the first thinker about natural phenomena in all history whom modern scientists feel they can identify with" [Cohen, 2010: p. 179]. In his debate with the Catholic Church on the structure of the Cosmos – the *geocentric view* (attributed to Aristotle and Ptolemy as its main authors) *vs. heliocentrism* – he defended the view that the Earth goes around the Sun rather than vice versa. While the Church argued from the evidence of Scripture, Galileo referred to his observations of the heavens through the telescope, a new technology in those times. The geocentric view was first seriously challenged in 1543 with the system of Copernicus, within which the Earth and the other planets revolved around the Sun. With the invention of the telescope in 1609, observations made by Galileo turned out to be incompatible with some tenets of geocentrism, and later were verified by other astronomers [Machamer, 2014].

However, Galileo's activity is considered very crucial for the origins of science not only because of his astronomic observations, but also due to his famous <u>thought experiment</u> and <u>the concept of idealization</u>, which he introduced into research. He made the innovative use of experiment and mathematics and, thus, initiated the methodological way for natural sciences to develop. A key figure in the scientific revolution of the modern era was **Isaak Newton**, a physicist and mathematician, who laid the foundations for <u>classical mechanics</u>. He continued to develop the theoretical basis of natural science. Together with other scientists and philosophers of the modern era, he established a field that is now termed as **theoretical physics**, which employs mathematical models and abstractions of physical objects and systems to describe, explain and predict natural phenomena.

What is important, the term "natural philosophy" was appropriated to the new natural science of Galileo and Newton. One of the most significant works by Newton is entitled *Philosophiæ Naturalis Principia Mathematica* (Latin for "Mathematical Principles of Natural Philosophy"). In the German tradition, *naturphilosophie* or philosophy of nature continued into the early 19th century as a speculative study trying to comprehend nature in its totality and in unity with spirit. From the mid-19th century, the term "natural philosophy" came to refer to physics [Buchwald, Hong, 2003: p. 166-169] and it is still used in that sense in degree titles.

The 19th century became the great time for a further development of physics and chemistry, as well as for the establishment of biology as a science due to Charles Darwin's evolutionary theory based on natural selection. The **profession of the scientist** in the modern usage of the notion also appeared in the 19th century, with the first university research laboratories. The first scientific laboratory devoted to both teaching and research was established in Germany at the University of Giessen in 1826. With the rise of technology-based industry in the German states during the 1860s, the scientific research faculties at the German universities became an asset to the country's industrial concerns [Atkinson, Blanpied, 2008: p. 33]. The 19th century was the time when science began to play an important role as a social institute.

The 20th century started with the development of quantum mechanics, and, in general, it became the period of a variety of astonishing discoveries and achievements in all natural sciences, as well as the appearance of new fields, such as neuroscience.

However, the rapid progress made it clear how dangerous science may be (the new destructive types of weapon, global ecological problems, etc.). The findings of genetics, the development of biotechnologies and the like have caused new ethical problems, which are still crucial and highly disputable. Neuroscience, as did once the evolutionary theory, has given new life to the views which reduce the social practices and mental states of people to naturalistic explanations [O'Connor, Joffe, 2013] – the position sharply condemned especially by some philosophers and humanitarians.

Unit 2. Scientific knowledge, its criteria and structure

When discussing the problem of the scientific criteria, one usually implies science as knowledge. Etymologically, the word *science* has its origins in the Latin verb *scire*, meaning "to know." Although, there are different ways to "know", for instance, through faith, authority, intuition, etc. Scientific knowledge is traditionally associated with the notion of **objectivity**.

The terms "objectivity" and "subjectivity", in their modern usage, generally relate to a perceiving subject and a perceived or unperceived object. The object is something that presumably exists independent of the subject's perception – something that would be there, as it is, even if no subject perceived it. The subject can perceive either accurately or in a distorted way. In this context, the term "subjective" typically indicates the possibility of perceptive error. Many philosophers would use the notion of "objective reality" to refer to anything that exists independent of any conscious awareness of it. Subjective reality would then indicate anything being constructed by a perceiving subject in its interactions with objects – and this reality depends on some conscious awareness of it [Mulder].

"Objective knowledge" can refer only to knowledge of an objective reality and ought to be clear from any perceptive distortions of the subject. In philosophy, the question whether we are able to know objective reality is considered arguable. As for science, it inherently implies the belief in our principal ability to know reality as it is. It does not mean that every scientist thinks strictly in this way. Scientists, especially theoreticians, may also doubt in the objective and true nature of their endeavor [Mulder]. Moreover, nowadays, all scientific knowledge is viewed hypothetical and open to refutations, rather than infallible. However, when it is about practice and applied research, scientists have to take the objects and phenomena they deal with as objective.

Thus, objectivity in science means both the existence of some objective reality and our ability of know it in a special scientific way of uncovering truths about the natural world. In doing so, we must eliminate personal biases, a priori commitments, emotional involvement, etc. [Reiss, Sprenger, 2015]. Objectivity is often attributed with scientific measurement, empirical testability and reproducibility. To be properly considered objective, the results of measurement must be communicated from person to person, which is implied by the notion of intersubjective certification. In other words, it should be possible for other investigators to ascertain the truth content of scientific explanation(s) [Malhotra, 1994]. Although the **question of the criteria of scientific knowledge** is complex and disputable, there are several general requirements a scientific theory must satisfy.

1) Empirical criteria:

• empirical testability [Chalmers, 1999: p. 38];

• an ability to lead to testable predictions or retrodictions (use of present information to infer or explain a past event) [Gonzales, 2013: p. 352];

• repeatability (reproducibility): the same phenomenon is sought again, and the interpretation given to it is confirmed or discarded by means of novel analysis and experimentation [Wilson, 1999: p. 58];

• mensuration: if something can be properly measured, using universally accepted scales, generalizations about it are rendered unambiguous [Tal, 2015; Wilson, 1999: p. 58].

2) <u>Non-empirical criteria</u>:

• logical consistency and consistency with the existing scientific knowledge [Mosterín, 2011];

• economy: scientists attempt to abstract the information into the form that is both simplest and aesthetically most pleasing [Wilson, 1999: p. 58].

• heuristics: the best theory stimulates further discovery, often in unpredictable new directions; and the new knowledge provides an additional test of the original principles that led to its discovery [Wilson, 1999: p. 58].

Those characteristics are usually taken as the criteria that set the science apart from other kinds of inquiries. As an example, they are considered to be able to distinguish astronomy, biomedicine, and physiological psychology from astrology, creation science and the like. The natural sciences lock together in theory and evidence to form the technical base of modern civilization. The pseudosciences lack the ideas or the means to contribute to the technical base. However, this question is highly debatable in the philosophy of science. For instance, not all hypotheses can be empirically tested, especially those in the social sciences and humanities. Another issue is about consistency with the existing knowledge, which provokes a question how then scientific revolutions and shift of paradigms are possible. Today, it is recognized that scientific theories at some point in their development can often be internally inconsistent or incompatible with other accepted findings (empirical or theoretical [Meheus, 2013: p. 3].

The **structure of scientific knowledge** comprises two general levels of research: empirical and theoretical [Stepin, 2006: p. 82].

1) <u>Empirical level</u> which includes a variety of empirical procedures, such as observation, comparison, tests and experiments, as well as empirical data.

In <u>*experiments*</u>, natural or artificial systems are studied in artificial settings designed to enable the investigators to manipulate, monitor, and record their workings, shielded as much as possible from extraneous influences, which would interfere with the production of epistemically useful data. Investigators who cannot experimentalize in this way can rely to some extent on *thought experiments* or sometimes on *natural experiments* (interactions in which natural mechanisms or other uncontrolled factors produce effects of interest to the investigator; for instance, diseases) [Bogen, 2008: p. 129].

Among the most significant elements of the empirical level one should note *facts* which are generally considered something that has really occurred or is actually the case. Scientific facts are tested by repeatable careful observations and measurement. Nevertheless, philosophers and historians of science since Kuhn have argued that facts are theory-laden. That is, facts can only be observed from within a theoretical framework and are, at least in part, determined by some theoretical setting. We cannot make theory-neutral observations [Bogen, 2014].

2) Theoretical level which includes theoretical constructs (hypotheses, theories, laws, principles, formulae, etc.) and a variety of methods (idealization, abstraction, hypothetical-deductive, inductive-empirical and axiomatic-deductive models of research, thought experiment, etc.).

There are three major **models of research**. The axiomatic-deductive model begins with a few axioms (self-evident truths) and from there uses the deductive method of logic to further the arguments. Deductive reasoning proceeds from one or more premises to a logically certain conclusion. If all premises are true, the terms are clear, and the logical rules are followed, the conclusion is necessary true. Here is the example of a deductive argument:

1. John is ill.

2. If John is ill, then he won't be able to attend our meeting today.

3. Therefore, John won't be able to attend our meeting today.

That argument is valid due to its logical structure. If 'ill' were replaced with 'happy', the argument would remain valid because it would retain its special logical structure:

1. P

2. If P then Q

3. So, Q [Deductive and inductive arguments]

The axiomatic-deductive model is generally employed in mathematics. Besides, it gives an appropriate way to organize knowledge.

The inductive-empirical model implies that research involves the collection of empirical data and their inductive generalization, as well as empirical tests. Consider the following argument:

1. Every raven in a random sample of 3200 ravens is black.

Therefore, probably,

2. All ravens are black.

An argument of this kind is often called an induction by enumeration of cases. The logical form of such arguments may be represented semi-formally as follows:

1. All observed X's are f.

Therefore, probably,

2. All X's are f [Deductive and inductive arguments].

The truth of the conclusion of an inductive argument is probable.

The most popular inductive approach to scientific method is sometimes called naïve inductivism, and it assumes that science begins by securing observed facts, which are collected in a theory-free manner. These facts provide a firm base from which the scientist reasons upward to hypotheses, laws, or theories. The naïve inductive method has been criticized in various ways, although the criticisms are mostly directed at extreme versions of the method – versions stating that observed facts can be known infallibly, or that empirical generalizations can be secured through the use of a strongly justified principle of induction [Haig, 2011: p. 1326-27].

The inductive-empirical model may be most appropriate at the initial stage of research when we know nothing of the phenomenon under study and have to start from zero. It is most suitable for a scientific discipline that has not developed any theoretical basis yet.

The hypothetical-deductive model proceeds by formulating a hypothesis in a form that could be tested on observable data: the scientist derives from the hypothesis one or more observational predictions, which are amenable to direct empirical test. If the predictions are supported by the data, then that result is taken as a confirming instance. If the predictions fail to agree with the data, then that fact counts as a disconfirming instance. Another account has been offered by Karl Popper, the philosopher of science, who construes the hypothetical-deductive method in falsificationist terms. According to him, hypotheses are viewed as bold conjectures, which the scientist submits to strong criticism with a view to refuting them.

Hypotheses that successfully withstand such criticism are said to be corroborated [Haig, 2011: p. 1327].

Even though the hypothetical-deductive method is used by many scientists, it has received considerable criticism. Leaving aside Popper's falsificationist version, the major criticism of the hypothetical-deductive method is that it is confirmationally weak. This weakness arises from the fact that any positive confirming instance of a hypothesis obtained through its use can confirm any hypothesis that is conjoined with the test hypothesis. Another criticism of the method is that it mistakenly maintains that hypotheses and theories arise through free use of the imagination, not by some rational, methodological, or logical means. However, one might overcome the confirmational defects by employing a Bayesian approach to confirmation within a hypothetical-deductive framework [Haig, 2011: p. 1327-28]. Despite the criticism, nowadays, the hypothetical-deductive model is considered the most common for natural sciences.

Unit 3. Philosophy of science, its scope and history

Todays, thanks to the permanent scientific and technological innovations, science has become one of the dominating human activities, the judge and authority in many areas of human life. This makes philosophy of science a crucially important part of philosophical speculation. As an area of philosophy, it investigates the variety of philosophical questions arising from science, its structure, components, foundations, methods, limitations, implications and so forth. It deals with both general questions about science (for example, what counts as science, what is a scientific method, what is a law of nature, the reliability of scientific theories, the rationality of theory choice, etc.) and more specific and foundational issues arising in different scientific fields. Hence, philosophy of science divides into a variety of areas such as philosophy of natural sciences (or even in a more narrow way – philosophy of physics, philosophy of biology, etc.), philosophy of social sciences and so on.

Philosophy of science overlaps with other disciplines which deal with various aspects of science. These disciplines include the history of science, science studies, sociology of science, psychology of science, etc. The history of science studies the historical development of science; it describes discoveries and inventions in specific scientific fields in some or other historic periods. It gives an empirical and factual base for theorizing on various philosophical problems of science. Science studies seek to situate scientific knowledge in a broad social, historical, and philosophical contexts. Sociology of science explores the structure of scientific communities, their interactions. Psychology of science deals with significant psychological issues of scientific work, scientific thought and behavior, including such phenomena as intuition, imagination, insight, etc.

The interaction between philosophy and the sciences has a very long history stretching back to **ancient Greek philosophy**. Plato and Aristotle (5-4 centuries BCE) are considered the first to distinguish the forms of approximate and exact reasoning, and set out the scheme of abductive, deductive, and inductive inference, etc. However, the precursors of philosophy of science were the philosophers of the 17^{th} and 18^{th} centuries with their focus on the nature of scientific knowledge and the methods to obtain it. Among the most influential names one can find Francis Bacon (1561-1626) – inductive method for scientific inquiry; René Descartes (1596-1650) – deduction as a reliable method, the method of radical doubt, substance dualism in the mind-body problem; David Hume (1711-1776) – the problem of induction; Immanuel Kant (1724-1804) – transcendental idealism (our experiences are structured by *a priori* forms of our mind, such as the concepts of space and time), his views on natural sciences (in the work 'Metaphysical Foundations of Natural Science'), etc. [Cohen, 2010; Grant, 2007].

The origins of philosophy of science are traditionally linked with **positivism** in its several stages: (1) the emergence of positivism as a philosophical movement –

1830-1890s (A. Comte, J. S. Mill, H. Spencer); (2) empirical criticism – 1870s-early 20th century (R. Avenarius, E. Mach, et al); (3) neopositivism – 1920s (M. Schlick, O. Neurath, R. Carnap, H. Reichenbach, et al). [Bourdeau, 2015; Pojman, 2011; Uebel, 2014]. These stages are followed by postpositivism, which emerges in 1950-1960s (T. Kuhn, K. Popper, et al) as a critique of positivism and an amendment to it.

It should be noted that a lot of reflection within philosophy of science has been performed on the material of natural sciences, rather than social sciences and humanities. The philosophical problems of these fields are traditionally considered by many scholars as having their own essential features and thus in many ways different from that of natural science.

The doctrine of positivism was founded in the early 19th century by **Auguste Comte** (1798-1857). The main principles of the positivism of that period can be summed up as follows. It radically breaks up with metaphysics. Positivism asserts that "metaphysical" problems are unsolvable, and scientific inquiry must be purified of any philosophical speculation. The mind must stop looking for causes of phenomena, and limit itself strictly to laws governing them. Science must stop trying to explain phenomena and answer 'why', and start to describe them and answer 'how'. We can only find out what is given in our sensual experience [Bourdeau, 2015].

Empirical criticism as an epistemological theory of knowledge was founded by **Richard Avenarius** (1843-1896). Another philosopher to significantly contribute to it was **Ernst Mach** (1838-1916). Empirical criticism states that the major task of philosophy is to develop a "natural concept of the world" based on pure experience. Traditional metaphysicians believed in two categories of experience, inner and outer. They held that outer experience applies to sensory perception which supplies raw data for the mind, and inner experience applies to the processes that occur in the mind, such as conceptualization and abstraction. As opposed to those views, empiriocriticism says that the subject-object dichotomy, the separation of inner and outer experiences falsify reality. We "introject" our feelings, thought, and will into experience and thereby split it into subject and object. By avoiding it, we could attain the original "natural" view of the world – the world in fact consists of neutral elements. Our experience must be distilled from the concepts of substance, causality and the like as *a priori* concepts of our mind. The goal of science is the simplest and most economical abstract expression of fact [Pojman, 2011].

Ernst Mach profoundly influenced the founders of the *Vienna Circle* and their movement of *logical positivism*, which, along with logical empiricism (the Berlin Circle), made up the more general movement of **neopositivism**. Logical positivism grew up in Vienna in the 1920s and 1930s. The central work for that movement was the '*Logical-Philosophical Treatise'* written by **Ludwig Wittgenstein** (1889-1951). They saw their task in clarification through the method of logical analysis of philosophical problems and assertions. There are two different kinds of statements: (1) reducible to simpler statements about experience, (2) non-reducible to such statements and thus meaningless. The first are empirical statements and thus become the subject of scientific inquiries. The second include metaphysical statements; hence, many philosophical problems are rejected as pseudo-problems. The final goal is unified science where every proper statement is reduced to the concepts of lower level which refers directly to the given experience [Uebel, 2014].

In this context, logical positivists formulate the principle of **verification** holding that statements are cognitively meaningful, rationally justifiable, if they can be verified either logically or empirically. Over the years many different formulations of verifiability ensued. In his 'Testability and Meaning' (1936) Rudolf Carnap revised in the way that all terms must be reducible to the observational language. However, this proved to be inadequate, and he replaced verification with conformation and sought to support the approach where probability of a statement is the degree of confirmation the empirical evidence gives to the statement [Ibid].

The procedure of verification or confirmation of theory logically or empirically involves the **problem of demarcation** of science from non-science, pseudoscience and the like. The proponents of verificationism stated that assertions become knowledge when they are verified by observations of the world, and that scientific knowledge is the sum of these verified propositions. Science progresses when scientists make assertions that have verifiable content. Their motive was to clean philosophy and science from metaphysics, its meaningless concepts, and assertions which do not state facts. However, there are a few significant problems with such an approach. For instance, there is no rigorous correspondence between what is observed and what is stated. Assumptions and biases creep into the descriptions of the simplest observations. Furthermore, verifiability as a criterion rejects too much from the human knowledge – not only the previous philosophical concepts but also a good deal of scientific terms, laws, and assertions. The history of logical positivism demonstrated how difficult it was to discover the absolute criterion of demarcation [Hansson, 2015; Thornton 2014; Uebel, 2014].

When discussing the **problem of scientific method**, philosophers of science often consider two types of reasoning – inductive and deductive. Thus, one answer to the question of method is what's called **inductivism**, which is the idea that <u>science essentially proceeds by making inductive inferences</u>. Inductivism is based on induction. Induction here is contrasted with deduction, and, as mentioned earlier, it does not guarantee the truth of the conclusion, which is probable. So consider this inference. Lots of swans that I have observed have all been white, therefore all swans in the nature are white. However, it could be that there is a black swan out there. Inductivism assembles a body of information of data through observation, and then using that body of information, it then formulates general conclusions about the world, which are based on inductive reasoning. This kind of reasoning is a rational way of drawing inferences about the world but it is the subject to much criticism [Langdridge, Hagger-Johnson, 2009: p. 9].

One who was very much opposed to inductivism as an account of the scientific method and verificationism as a true criterion of scientific knowledge was **Karl Popper** (1902 – 1994), an Austrian-British philosopher. Popper argued that inductivism was far too inclusive a way of thinking about the scientific method, because it allowed certain types of inquiry as being genuinely scientific, even though by his likes they weren't. The two examples that Popper focused on were Marxism and Freudianism. In fact, he did not reject the issue of demarcation science from pseudo-science but for he offered an alternative way for doing it [Thornton 2014].

What Popper came up with is a view known as **falsificationism**, according to which the scientific method is actually essentially deductive. According to him, scientists make bold conjectures about the way the world is, and then seek to refute, to falsify their bold guesses. Thus, you may make lots of observations of swans and see that they are all white, and on that basis you might make a bold conjecture by saying that all swans are white. Then, the scientific enterprise consists of trying to find the counterexample, for example the black swan, which falsifies the bold conjecture. Popper thought is that genuine science is a type of inquiry that issues in these bold conjectures, which are very clearly framed such that one can falsify them. In this respect, Marxism and Freudianism may seem to make assumptions of a scientific nature but those assumptions are never falsifiable. There's no way of testing and falsifying them [Langdridge, Hagger-Johnson, 2009: p. 10; Thornton 2014].

Before Karl Popper developed falsificationism as a possible method of science, at the turn of the 20th century the French physicist and philosopher **Pierre Duhem** had already made an important discovery. According to him, scientists never test hypotheses in isolation, but always with a set of other hypotheses, both main theoretical hypotheses and auxiliary ones. Consider for example Newton's Law of Gravity. We never test Newton's Law of Gravity by itself, but always in conjunction with a set of hypotheses. Some of those hypotheses are main theoretical hypotheses, for example, Newton's Three Laws of Motion. Others are auxiliary hypotheses, for example the hypothesis about the number of planets in the solar system, their masses, whether gravitational attraction among planets is weaker than the attraction between the sun and the planets, and so on. This is what philosophers of science call the problem of **underdetermination of theory** by evidence. Very often our experimental evidence is not enough, is not sufficient to determine the choice between tweaking or modifying one auxiliary hypothesis as opposed to replacing altogether a main theoretical hypothesis [Stanford, 2013].

One more philosopher of science whose work has been hugely influential in the field is Thomas Kuhn's seminal 1962 book entitled 'The Structure of Scientific Revolutions'. It changed our way of thinking about science. **Thomas Kuhn** (1922 –

1996) is an American philosopher and historian of science. He came to the conclusion that probably science doesn't have a distinctive method, no matter whether it's inductive or deductive, and that probably also we need to rethink the notion of progress in science, and how science is meant to deliver true theories [Bird, 2013].

Before Kuhn, philosophers of science had a certain picture of how science grows and unfolds based on a sequence of scientific theories each of which were supposed to build on its predecessor and improve on its predecessor by delivering a more accurate and adequate image of nature. According to Kuhn, if we look at the actual scientific evidence, we obtain a radically different image of how science grows. Kuhn argues that science goes through periods of normal science, crisis, and scientific revolutions. In periods of normal science, scientists work within a **scientific paradigm** which includes the main scientific theory, the experimental and technological resources and those by the community at the time, as well as the system of values of the community – values like simplicity, mathematical elegance, parsimony and others [Ibid].

During periods of normal science, according to Kuhn, a scientific community works within a well-defined framework, and there is no attempt to falsify or refute a scientific theory. The accepted scientific paradigm undergoes a period of crisis only when a sufficiently large number of anomalies accumulate. During periods of crisis, a new paradigm may come to the fore, and the scientific community may decide to abandon the old paradigm and shift to the new one. This is what Kuhn called the paradigm shift. Kuhn, however, stressed that the process of theory choice is not dictated by the superiority of the new paradigm over the old one. On the contrary, the new paradigm should only be able to have a higher puzzle-solving power than the previous one, be able to solve the anomalies, which the previous paradigm wasn't able to solve. Thus, Kuhn redefined the whole idea of how science progresses, not in terms of scientific theory being true or more likely to be true, but rather in terms of their capacity for solving puzzles and problems, as well as other factors including scientific conventions. However, on the whole, paradigms are incommensurable that is they lack a common measure to assess and evaluate which of them is better or superior. Different scientific paradigms use very different theories, concepts, and also different experimental, technological resources, and system of values – the problem called the <u>incommensurability of scientific theories</u> [Bird, 2013; Kuhn, 2012].

An astonishing view on science is given by an Austrian-born philosopher of science **Paul Feyerabend** (1924 – 1994), widely known for his book ‘Against Method’ and the conception of the **epistemological anarchism**. He began his work in philosophy by attacking the above-described ideas. For example, he showed that falsifying a theory is not such an easy thing. Very often, scientists keep a theory alive after it appears to have been falsified. Sometimes keeping a theory alive in the face of apparent experimental contradiction turns out to be the right thing to do. You cannot tell which situation you are in. Different scientists adopt different viewpoints. There is no general rule for when to abandon a theory and when to keep it alive [Preston 2012].

Feyerabend also attacked the whole idea that method is the key to scientific progress. He argues that there are no useful and exceptionless methodological rules governing the progress of science or the growth of knowledge. The only "rule" a general methodology might contain will be the suggestion: "**anything goes**". Thus, science isn't really a method at all in the strict sense of that term. Rather, it is a label we use to describe the testing and verifying of differing ideas and maps we have about the world. Science, he insists, is a collage, not a system or a unified project. Science is one of various belief-systems, and together they are all aiming to give us knowledge of the world . Here, "objectively" may be nothing to choose between the claims of different belief-systems, say, between science and those of astrology, voodoo, and alternative medicine. They all have an equal epistemic status [Ibid].

Feyerabend's critique of science gave him the reputation for being an "anti-science philosopher", "the worst enemy of science". However, this is not quite true. As Lee Smolin argues from his own conversation with the philosopher, Feyerabend knew quite a lot of contemporary physics, and "he was more conversant with the technicalities than most philosophers" (Smolin, 2006: p. 292). He, rather, considered the question of why science worked as unanswered. "Feyerabend was convinced that science is a human activity, carried out by opportunistic people who follow no general logic or method and who do whatever it takes to increase knowledge (however you define it)." (Ibid.).

It should be noted that over the past three decades, philosophy of science has grown increasingly "local" in the sense that it has switched its focus from general features of scientific practice to puzzles, issues, and concepts specific to particular disciplines including interdisciplinary areas, such as neuroscience.

Unit 4. The problems of unification of sciences

A very important problem in the philosophy of science is the problem of unification of sciences. It includes the following questions: Is there one privileged, most basic level of explanation which would embrace all phenomena? Can the various sciences be unified into a single overacting theory? What about matters of method, institutional, ethical and other aspects of the unification? [Cat, 2014] The list of questions may be continued.

The questions about unity belong to a tradition of thought that can be traced back to *pre-Socratic Greek cosmology*, in particular to the problem of the one and the many. Is there one fundamental something to be the source of everything? Is there an infinite set of basic units which are simple and indivisible? Among the possible answers given by Ancient philosophers one may find Parmenides' static substance, Heraclitus' flux of becoming, Empedocles' four elements, Democritus' atoms, Pythagoras' numbers, Plato's forms, and Aristotle's categories. According to Aristotle, different "sciences" know different kinds of causes, and it is metaphysics that comes to provide knowledge of the underlying kind. With the advent of *Christian monotheism*, the organization of knowledge reflected the idea of a world governed by the laws created by God [Ibid].

The emergence of distinctive fields of scientific knowledge addressed the question of unity through the designation of a privileged method. In the 16th century the British philosopher *Francis Bacon* held that the unity of sciences was the result of the organization of discovered material facts in the form of a pyramid with different levels of generalities. At the turn of the 17th century, *Galileo* stated that the Book of Nature had been written by God in the language of mathematical symbols and geometrical truths. In the 17th century, *Newton's mechanics* became the most promising framework for the unification of natural philosophy. Not only the objects of nature were explained within the mechanical approach, but also the function of a human body (Rene Descartes) and even the human society (Thomas Hobbs) received the mechanical explanation [Ibid].

The German philosopher *Immanuel Kant* (the 18th century) saw philosophy as the area which determined the precise unifying scope and value of each science. The unity of science is not the reflection of a unity found in nature; rather, it has its foundations in the unifying character or function of reason itself. Unity is a regulative principle of reason, an ideal guiding the process of inquiry. Kant gave philosophical tendency to the notion of <u>world-view</u> (Weltanschauung) and, indirectly, <u>world-picture</u> (Weltbild), thereby establishing among philosophers and scientists unity of science as an intellectual ideal [Ibid].

In general, there are *two opposite approaches* to the unification. The first can be conventionally called **naturalism** stating <u>the unity of scientific method</u> within the epistemological framework of natural science. Its achievements in the wake of scientific revolutions and permanent technological innovations seem most impressive. Natural sciences are “manifestly progressive”, their theories “tend to increase in depth, range and predictive power” [Gorton]. Besides, they are more consensual. Hence, social sciences and humanities should import their aims, methods and concepts. Several most famous examples include *Auguste Comte*, who coined the term “positivism” and advocated the image of sociology as “social physics” (19^{th} century); *John B. Watson* who established behaviorism in psychology, which was seen as a purely objective experimental branch of natural science studying behavior, not consciousness (20^{th} century). The core tenets shared by contemporary advocates of the unity of science are as follows: the view of science as a fundamentally empirical enterprise, and its primary aim is to produce causal explanations grounded in law-like regularities, as well as to describe and explain the world, not to make value judgments (value neutrality) [Gorton].

The opposition to that unity already emerged in the 19^{th} century as a **specifically humanitarian philosophy,** which includes such scholars as *Johann Droysen*, *Wilhelm Windelband*, *Wilhelm Dilthey* and others. They emphatically stated a <u>deep difference between traditionally humanistic areas and natural sciences</u>. The studies were divided into *Naturwissenschaft* (natural science) and *Geisteswissenschaft* (“sciences of spirit”) or *Kulturwissenschaft* (culture science), each having its own object of study and methods. The first is aimed at linking phenomena into generalized groups and defining generalizing laws of nature; their method is explanation. The second studies contingent, individual, and often subjective phenomena such as individuals with their unique life histories, and thus is aimed at understanding, comprehending phenomena and the meaning of them [Cat, 2014]. The human scholars apply hermeneutics as the general method of interpretation of texts and even human actions, their meaning, as well as all products of such actions, “all manifestations of the human spirit” (Dilthey). Today, the humanitarian approach to science seeks to understand human experience in subjective, personal, historic, interpretative, participatory, contextual terms.

The <u>split</u> between two major areas of research – natural science and the humanities – was fixed by **Charles Snow**, an English physical chemist, in his widely famous public lecture ‘<u>The Two Cultures</u>’ (1959) [Snow, 1993]. That thesis became very popular and influential. In fact the lecture specifically criticized the British educational system, as having acknowledged much more the humanities at the expense of scientific education. However, in many ways the idea of the split was considered by many as relating to the whole community of scientists and scholars, and it provoked widespread and fiery debate. Some scholars objected to such an empathetic distinction. For example, *Fritz Staal*, a Vedic scholar and Professor of Philosophy, holds a kind of **cognitive unification** stating a fruitful cooperation between them in the form of the original conceptions. As an example, the universal grammar theory is given. It has been proposed by the linguist and cognitive scientists Noam Chomsky, and it tells that the principles underlying the structure of language are biologically determined in the human mind and hence genetically transmitted [Staal, 1998: p. 54].

The issues of the scientific unification imply **the problem of truth and objectivity**. If there should be a universal scientific method aiming to give us objective knowledge, we must define what is objectivity. Besides the ontological aspect of its understanding, which has been discussed earlier, and its relation to the scientific criteria, objectivity may be considered in the context of two opposite epistemic positions which are relativism and realism. As for the former, it questions the issue of objectivity itself. **Epistemic relativism** claims that there are no framework-independent facts about which norms of justification, standards of rationality or the like are right, but that there are different positions on such things relative to particular frameworks. Put another way, we can disagree about what counts as good evidence or strong justification without being inconsistent, irrational, unintelligent, unjustified. The label "normative" is relative depending on our standards of rationality and reasonableness to guide, evaluate, and criticize reasoning, both our own and that of others. The strongest version of epistemic relativism allows any epistemic standards or norms to be correct and, thus, it is implausible, while more subtle versions are rather considered seriously [Swoyer, 2015].

A position which stands very much opposed to epistemic relativism might be called **scientific realism**. It says that science is trying to give us objective evidence which enables us to find out about objective truth about the world [Ibid]. Scientific progress therefore, consists in the amassing of greater amounts of scientific evidence of an objective kind, which leads us closer to gaining the truth about the world. We have an objective way of gaining scientific evidence and therefore of settling scientific disputes. The farther away from the philosophical problems of the theory and the nearer to practice, the closer the scientist is likely to be to scientific realism.

Unit 5. Natural Science and its place in scientific knowledge

Natural science is a branch of science concerned with the description, explanation, and prediction of natural phenomena. Natural science can be broken into two main branches: *biological science* and *physical science*. Physical science is further broken down into branches, including physics, astronomy, chemistry, and earth science. All of these branches are divided into many fields. The distinctions between them are not always sharp and clear, and they share a number of cross-discipline fields. Physics, for example, plays a significant role in other natural sciences, as can be seen in astrophysics, geophysics, chemical physics and biophysics. Likewise, chemistry is represented by such fields as biochemistry, chemical biology, geochemistry and astrochemistry.

Natural science historically developed out of philosophy or, more specifically, **natural philosophy**. Modern meanings of the terms science and scientists date only to the 19th century. The naturalist-theologian William Whewell was the one who coined the term "scientist." One of most famous examples of the application of the term "natural philosophy" to what we today would call "natural science" is Isaac Newton's 1687 scientific treatise, which is known as ‘The Mathematical Principles of Natural Philosophy’ [Smith, 2008]. Natural philosophy pertains to the work of analysis and synthesis of common experience and argumentation to explain or describe nature.

It is generally common to state that the emergence of modern science was in some significant sense dependent on the existence of a well-developed natural philosophy. That area of study originated in Ancient Greece and reached its mature development in the late Middle Ages, after it became a required subject in the medieval universities. But, at that time, sciences, such as astronomy, optics, and mechanics, already existed independently of, but concurrently with, natural philosophy. They were mathematical disciplines, and their problems were supposed to be resolved only by mathematics. For example, cosmic problems were the domain of natural philosophy, whereas planetary positions were the responsibility of mathematical astronomy. To evolve into some form of modern science, the exact mathematical sciences had to be integrated with the relevant subject matter in natural philosophy. With the establishment of the universities of Paris, Oxford, and Bologna by 1200, the institutional foundation was laid for the development of modern science. The development of natural philosophy with its emphasis on reason and its inquiring spirit was the major activity of universities [Del Soldato, 2012].

The term *science*, as in natural science, gained its modern meaning when acquiring knowledge through experiments (special experiences) under the scientific method became its own specialized branch of study (in the 16th and 18th centuries). In the 14th and 15th centuries, natural philosophy referred to what is now physical science. From the mid-19th century, when it became increasingly unusual for scientists to contribute to both physics and chemistry, it just meant physics. In the English-speaking scientific community, it has been for a long time considered that the term *science* comprises natural and exact sciences, while human disciplines have been mostly referred to as *human studies* or *liberal arts*. The tradition is still alive, to some extent. However, nowadays, such notions as *social sciences* and *human sciences* have become very common. One may also find such notions as cultural sciences and even literary science (e.g., the Department of Social and Cultural Sciences of Marquette university, E. O. Wilson Literary Science Writing Award, etc.).

It is generally believed that natural science, as opposed to social and human sciences, studies what one can call the merely **physical matter in all its forms** [Ingthorsson, 2013: p. 26-27]. This matter is usually taken as unconscious, though some scientific disciplines, traditionally classified as natural sciences, e.g. medicine and biology, do study conscious beings, like humans. To be exact, they only study the physiology of humans, the functions of the body quite independently of what goes on in the consciousness of the person inhabiting that body. However, when medicine diverts its attention to the investigation of a patient's wishes, wants and preferences (e.g. psychosomatic disorders) – things that we are at present unable to adequately understand in physical terms – it is no longer involved in pure natural science. Typically, the study of psychosomatic disorders suffers from the same criticism as the human sciences (lack of decisive evidence and strict laws that can give accurate predictions and/or treatments). The most important aspects of the study of the merely physical, from this perspective, is that everything in the physical domain, as assumed, is (1) governed by natural laws, and (2) mind-independent. It has a certain nature independently of what we happen to believe about its character [Ibid].

The characteristics of natural science can also be considered in terms of the shift of **scientific world pictures** – the concept developed by the Russian philosopher **Vyacheslav S. Stepin** (b. 1934). He assumes the existence of three major scientific world pictures, namely, classical, non-classical, post-non-classical) [Stepin, 2006: p. 117]. Each of them is characterized by a special system of ideals, standards, and strategies of research, as well as by different perspectives of reflection on science. The European science started with the acceptance of the classical world picture, which was based on Newton's mechanics. Its explanatory standard was strict causality. The object and subject of research were supposed to be strictly separated from one another, and philosophers sought to clear the process of cognition from all of the subjective [Stepin, 2006: p. 188].

The non-classical world picture appeared in the early 20th century. It was influenced by the quantum theory and theory of relativity, as well as by uncertainty principle and the principle of complementarity. The subject and object of research are sometimes viewed as interacting. In the middle of the century, philosophers become more inclined to speak about science in terms of epistemic relativism and probability

[Stepin, 2006: p. 248]. The post-non-classical world picture was initiated in the second half of the 20th century by the works of the Belgian physical chemist *Ilya Prigogine* (1917-2003), noted for his dissipative structures theory which led to research in self-organizing systems. According to Prigogine, determinism loses its explanatory power in the face of irreversibility and instability [Stepin, 2006: p. 321]. However, the concept of scientific world pictures is not widely acceptable in the philosophy of science.

Unit 6. Philosophical problems of physics

The philosophy of physics studies the fundamental philosophical questions underlying modern physics. It began by reflecting on the basic metaphysical and epistemological questions, such as causality, determinism, the nature of physical law, etc. Among the issues being discussed within the contemporary dimension of philosophical problems of physics are the following:

• space, time;

• energy, work, randomness, information, and others as studied by thermodynamics;

• determinism vs. indeterminism, the uncertainty principle, complementarity and other issues of quantum mechanics.

Since the beginnings of the ancient Greek natural philosophy roughly 2,500 years ago, scientific issues and philosophical issues have had strong influences on one another. To take just one example, in the western world for much of the period from the ancient Greeks to the 1600s, the universe was broadly conceived of as a teleological universe, that is, a universe with natural goals and functions. With the scientific changes in the 1600s, and the mechanistic approach (that is, a non goal-directed, but causality-oriented approach) of fundamental sciences such as Newtonian physics, the general conception of the universe changed to a more mechanistic universe. It became to be viewed as a machine, sort of a clock-like universe. Early in the 20th century, two important new theories arose in physics, namely Einstein's theory of relativity and quantum theory. Both of them have non-trivial consequences for certain deeply held beliefs about the sort of universe we inhabit [De Vitt, 2010: p. 129-130].

In addition, since about the time of Newton, we have come to view the physical sciences in a unified way, with physics investigating phenomena at the most basic level (for example, quantum theory investigating phenomena primarily at the sub-atomic level). Here we have a problem of **reductionism** when <u>the nature of complex things is understood by reducing them to the interactions of their parts</u>, for instance, explain biology in terms of physics and chemistry. Scientists tend to view chemistry as investigating phenomena at a somewhat higher level, at the level of entities, for example, atoms and elements, composed out of the more basic entities investigated by branches of physics such as quantum physics. They likewise tend to view biology as investigating phenomena at a yet higher level. In general, the physical sciences are viewed as unified in the sense of investigating the same world, albeit at different levels [Fang, Casadevall, 2011: p. 1401-2]. Within such a reductionist approach, physics is typically regarded as investigating the most basic level. By contrast, **holism** as an opposite view, claims that <u>the complex systems are inherently irreducible, and more than the sum of their parts</u>. However, nowadays, holism is considered rather a philosophical conception, and is not taken so seriously in the natural sciences as they think of reductionism.

Relativity and quantum theory both have substantial implications for some of our more broadly philosophical questions. **Relativity theory** has surprising implications for many of our traditional views, for example, our traditional views on the **nature of space and time**. We have long assumed that space and time are independent of one's point of view. But scientists have found that time passes at different rates for different reference frames, and that distances likewise will differ depending on one's frame of reference [De Vitt, 2010: p. 130-131].

In 1905, **Albert Einstein** (1879–1955) published a paper containing the core of what would come to be known as the Special Theory of Relativity. In 1916, he published the General Theory of Relativity. Both the special and general theories have intriguing consequences for some long-held beliefs – for example, beliefs about the nature of space and time, the replacement of the traditional Newtonian view of gravity as a mutually attractive force, the relativity of simultaneity, and the like [De Vitt, 2010: p. 130].

At its core, what came to be called the *special theory of relativity* is based on two fundamental principles. One of these principles is what Einstein termed the "principle of relativity," and the other is what is often referred to as the principle of the constancy of the velocity of light [De Vitt, 2010: p. 132]. Einstein sums up the **principle of relativity** as the principle that "the laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good" [Einstein, 1952a: p. 37]. The key idea is that we are dealing with straight-line motion at uniform speed. In the 1905 paper, Einstein was primarily concerned with electrodynamics and thus he spoke of the laws of electrodynamics. Nevertheless, the principle of relativity can be (and usually is) generalized to include all laws of physics, that is, the basic idea is that the laws of physics are the same in all inertial reference frames [Ibid]. The other basic principle of the special theory of relativity is what is often termed the "**principle of the constancy of the velocity of light**," (PCVL) [De Vitt, 2010: p. 132]. It says that "light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body" [Einstein, 1952a: p. 38]. This means that if one measures the speed of light in a vacuum, the value will always be the same. From these two principles one can deduce some surprising consequences for our usual notions involving space and time [De Vitt, 2010: p. 132].

One implication of special relativity is that time moves at different rates in different reference frames, and thus it is possible to have twins who are no longer the same age (the "*twin paradox*"). Besides, we also have a more general implication that there is no "right" point of view, that is, there is no privileged reference frame – there are simply different reference frames, and no one is any more "right" than any other

[De Vitt, 2010: p. 136-137]. Thus, we have a **broader epistemological dimension of relativity** as an approach which vividly illustrates how wrong we can be about beliefs that seem so obvious. Before being introduced to relativity theory, it seemed just obvious and unquestionable that time moved along at the same rate for everyone. In short, relativity warns us to be more cautious about the degree of confidence we have in beliefs that seem obviously correct [De Vitt, 2010: p. 161].

As for the *general theory of relativity,* it is based on two fundamental principles. The first principle is what Einstein often referred to as the “general principle of relativity,” but which is now more often termed the **principle of general covariance**. It removes the special circumstances of applying only to inertial reference frames [De Vitt, 2010: p. 140]. As Einstein phrased the principle, the “laws of physics must be of such a nature that they apply to systems of reference in any kind of motion” (Einstein, 1952b: p. 113). In other words, the laws of nature are the same in all reference frames. The second basic principle on which the general theory of relativity is based is usually termed the **principle of equivalence**. It says, roughly, that effects due to gravity and effects due to acceleration are indistinguishable [De Vitt, 2010: p. 140].

Subsequently, Einstein provided the key equations (usually referred to as the **Einstein field equations**) that would satisfy the requirements of these principles. Solutions to these equations indicate how space, time, and matter influence one another, and these equations are the mathematical core of general relativity [De Vitt, 2010: p. 141]. Time, space, and simultaneity are affected. That is, how much time passes, how much space an object occupies and what the distance is between points, and whether events are or are not simultaneous, varies from one reference frame to another.

Another curious consequence of general relativity has to do with the **curvature of spacetime**. Thus, instead of thinking of an object as moving through space, we can think of it as moving through a system of coordinates which track both locations in space as well as locations in time, that is, spacetime [De Vitt, 2010: p. 143]. In classical physics, space is a three-dimensional Euclidean space where any position can be described using three coordinates. Special and general relativity uses spacetime which is modeled as a four-dimensional continuum.

Both the special and general relativity suggest that suitable geometries of spacetime, or certain types of motion in space, may allow **time travel** into the past and future. However, it implies serious philosophical and methodological problems. Most scientists believe it highly unlikely, as it violates causality, i.e. the logic of cause and effect (the grandfather paradox). As for the methodology, there is no experimental evidence of time travel, making it a speculative hypothesis [Smith, 2013].

Another twentieth-century development with surprising implications is **quantum theory**, a branch of physics that is primarily used for situations involving atomic-or-smaller levels. By the early 20th century, physicists encountered a number of experimental phenomena that did not fit comfortably into the existing theoretical framework. One of the earliest has come to be called the *"two-slit" experiment*. It is within the problem of whether entities such as electrons are particles or waves. The concept of **wave-particle duality** says that every elementary particle or quantic entity exhibits the properties of both particles and waves [De Vitt, 2010: p. 148-151].

If we go beyond the experimental results, we may consider a philosophical question concerning reality. In particular, what sort of reality could produce these sorts of results? On the one hand, the wave effect we find in the basic two-slit experiment seems like it could only be produced if the electron is really a wave. In contrast, the particle effect we find suggests that electrons are particles. To push this **reality problem** a bit further, recall that the wave effect we find in the basic two-slit arrangement could seemingly only be produced if electrons pass through both slits simultaneously. And the particle effect we see when the detectors are turned on, and the behavior of the detectors, could seemingly only be produced if electrons are passing through one slit or the other but never both slits simultaneously. But the question arises of how could an electron "know" whether the detectors are on or off? [De Vitt, 2010: p. 151]

There are no agreed-upon answers to these reality questions. The more philosophical issue of what sort of reality could produce these experimental facts, remains deeply puzzling. These and other puzzling results helped lead to the development of quantum theory. This is a good point to bring up a topic, namely, the issue of **instrumentalist and realist attitudes towards theories**. An instrumentalist is one who looks to a theory primarily to make accurate predictions, without concern for whether the theory reflects the way things "really" are. One, who takes a realist approach, wants a theory not only to make accurate predictions, but also to provide a picture or model of reality. Most physicists working with quantum theory tend to take an instrumentalist attitude toward the theory, without worrying about the sorts of reality questions discussed above. This is a perfectly reasonable and understandable attitude for a working physicist [De Vitt, 2010: p. 151-152].

Among the perplexing philosophical issues of quantum mechanics there exists an opposition between determinism and indeterminism. **Determinism** is a position which became mainstream after Newton. It says that the universe is governed by strict natural laws that can be discovered and formalized by means of scientific observation and experiment, and thus seems to preclude the possibility of free will. This means that both natural objects and human beings are governed by strict and universal laws. By contrast, indeterminism says that a physical object has an ontologically underdetermined component.

In this context, another issue is relevant. This is the so called **uncertainty principle** which appeared as an answer to the wave-particle puzzle. It was formulated in 1926 by Werner Heisenberg. It states that the more precisely the position of some particle is determined, the less precisely its momentum can be known, and vice versa. Thus, uncertainties, or imprecisions, always turned up if one tried to measure the position and the momentum of a particle at the same time. Heisenberg concluded that these uncertainties in the measurements were not the fault of the experimenter, but fundamental in nature. Within the Copenhagen interpretation of quantum mechanics the uncertainty principle was regarded as a property of the physical reality which does not exist in a deterministic form, but rather as a collection of probabilities, or possible outcomes [Hilgevoord, Uffink, 2014].

Another idea crucial in quantum mechanics is **complementarity** of Niels Bohr. Such kind of a phenomenon is the particle and wave aspects of physical objects. It says that light can act both like a particle and like a wave depending on a measuring device. Complementarity has a profound aspect being applied to the physical world. All properties of physical entities exist only in pairs. Together with the uncertainty, it says that all properties and actions in the physical world manifest themselves as non-deterministic to some degree [Faye, 2014].

Thus, the philosophical implications of *quantum theory* seem very dramatic. Scientists and philosophers have always been interested in the general question of the sort of universe we inhabit. What is exciting about recent results involving quantum theory is that these results do not seem to allow for any sort of a “normal” picture of reality. Moreover, some more recent results have ruled out a large class of possible models of reality. In general, both relativity theory and quantum theory have forced us to rethink some of our most basic and long-held beliefs.

Unit 7. Philosophical problems of astronomy and cosmology

Astronomy is a natural science studying celestial objects (such as stars, galaxies, planets, asteroids, etc.), their physics, chemistry, and evolution, and phenomena that originate outside the Earth atmosphere (such as gamma rays, cosmic microwave background radiation, etc.). *Cosmology* is a part of astronomy and studies the universe as a whole, its origin, evolution, and the future. The *universe* is the totality of existence, i.e. everything that exists, including celestial objects, intergalactic space and its content, the smallest subatomic particles, all space-time, matter, and energy.

Cosmology is the attempt to understand in scientific terms the structure and evolution of the Universe as a whole. Although it is a modern science, many of the philosophical relevant questions related to current cosmology are old. Did the universe come into existence a finite time ago? Will it come to an end? Why are the cosmic evolution and the laws of nature of just such a kind that they permit intelligent life to exist? These and other questions are currently being discussed in the light of the most recent cosmological theories and observations.

The pursuit to understand the nature of the Universe dates back to Ancient Greece. Modern cosmology is dramatically different from that of Pythagoras, Plato and Aristotle, whose cosmological thinking was closely related to their philosophical ideas, and it shaped the field of cosmology at least up to the times of Copernicus and Kepler. Nowadays, one may still argue that cosmology is even more philosophical than most other sciences, as it more explicitly deals with the limits or horizons of scientific knowledge [Zinkernagel, 2014]. Thus, a crucial problem is connected with a **scientific status of cosmology**.

For centuries cosmology was regarded as a branch of metaphysics rather than a science. Newton's book 'Mathematical Principles of Natural Philosophy’ laid the foundations of modern physics by providing testable laws of nature. That could explain a variety of observable phenomena from free fall to planetary motion, but did not explain how planets and stars formed, how they evolved, what set them in motion. One of the first attempts at a scientific explanation of the origins of the universe according to Newton’s physics was the *Kant-Laplace nebular hypothesis* proposed at the end of the 18th century. In his 1755 book 'Universal Natural History Interior of the Heavens’ Immanuel Kant claimed that at the origin of the universe, space was filled with what he called the fine matter on which two fundamental forces acted, namely attraction, capable of lumping matter into what became planets and stars, and repulsion counterbalancing attraction and causing matter to whirl in vertices that would eventually become planets and stars. Yet, Kant himself was skeptical about the possibility of developing cosmology as a science, because the very metaphysical idea of a universe having a beginning in space and time seemed fraught with contradictions [Massimi, Peacock, 2014a, p. 15-16].

The path to cosmology as a science was very long. Cosmology faces **three distinct methodological problems** as a science: whether our current laws apply to the early universe; the uniqueness of its object of study; and the unobservability of large portions of the universe [Massimi, Peacock, 2014a, p. 16-18]. The first problem arising in cosmology is the applicability of the laws of nature to the origins of our universe. Can the laws of nature apply to the origin of our universe? Did our laws come into existence with our universe? How can we extrapolate from the present physics and its laws, to the origins of our universe? The second problem for cosmology to have the status of an experimental science is the possibility to run experiments to test hypothesis. This typically involves being able to repeat the test more than once, and on several different samples of the same object. However, we have only one universe to observe and to experiment upon. Cosmology's major difference from the other natural sciences is the uniqueness of its object of study – the Universe as a whole. Thus, if testability so conceived is a distinctive feature of experimental science, cosmology seems to face a problem.

The third problem with cosmology is the unobservability of large portions of the universe. It concerns the extent to which we extrapolate information from our current vantage point, our planet earth, to the universe as a whole. The amount of information we can access from our current vantage point, considering the speed of light limit, which restricts how far back into the history of our universe we can, so to speak, observe, is restricted to events in the so-called past light cones, parts of the universe that have been able to send information to us. This is known as the horizon problem. In an accelerating universe like ours, there exists an event horizon. Points sufficiently far apart from each other will never be in contact. That means there are bound to be vast regions of our universe that will remain unobservable to us forever. There are limitations on our ability to observe both to very distant regions and to very early times.

The hypothetical character is incorporated in the **basic theory of modern cosmology**. Cosmology starts by assuming that the laws of physics are the same everywhere, and underlie the evolution of the universe. Gravity is the only known force acting effectively on astronomical scales. Consequently, cosmological theory describing all but the very earliest times is based on the classical relativistic theory of gravitation, namely Einstein's General Theory of Relativity, with the matter present determining space-time curvature and hence the evolution of the universe [Ellis, 2007].

Despite these philosophical and methodological problems, cosmology came a long way from the time of the Nebular Hypothesis and has established itself as a science in its own right. The striking advances in cosmology have become possible by the **technology of telescopes**. Throughout this universe of galaxies, we are able to see how things have changed with time due to the fact that light travels at a finite time. The further away scientists are looking, the further back in time they are seeing.

It was found out that the universe of galaxies is relatively uniform, which means that by studying part of the universe, we are learning something that is statistically representative of the whole.

However, cosmology can be still considered less satisfactory subject, compared to other natural sciences. Due to its nature, it is different from any other branch of the natural sciences because of a somewhat speculative nature of the cosmological models. Consequently, it is inevitable that philosophical choices will to some degree shape the nature of cosmological theory, particularly when it moves beyond the purely descriptive to an explanatory role. These philosophical choices will strongly influence the resulting understanding [Ellis, 2007].

There are several **cosmological models** trying to describe and understand the universe, such as *Static or Newtonian universe* (steady state and infinite), *Einstein's models* (one as static, dynamically stable, neither expanding or contracting, and the other as Oscillating universe), *Big Bang model* (describing the universe as originating in singularity and expanding ever since), *Steady State universe model*, *Inflationary model*, *Multiverse* (an existence of many universes), etc. The mainstream model is that of the Big Bang. The first model of an expanding universe was proposed by Willem de Sitter, a Dutch mathematician, physicist and astronomer, although initially it was not appreciated. But since the late 1920s, there have been cosmological models as describing expanding spacetimes. Generalization of expanding models to cases containing matter and radiation by Friedman in 1922 and 1924 showed that the origin of the expansion lay in a singularity at a finite time in the past – the *Big Band*, the most dramatic event in the history of the universe: it is the start of existence of everything. With the discovery of the cosmic microwave background (the CMB) in 1965, this hot origin of the universe became the accepted view. The early universe should be hot, and dominated by the density of relativistic particles. Gradually the universe cooled sufficiently to become neutral. It is extremely hardly possible to ask what came before such a time, and yet the universe at this point must be set up in a special uniform state [Massimi, Peacock, 2014a, p. 20-24, 30].

The current cosmological model is the so-called *concordance model*, or lambda CDM. This model builds on Einstein's general relativity and the so-called Friedmann-Lemaitre-Robertson-Walker model, and asserts that our universe is infinite and consists of 5% ordinary matter, 25% cold dark matter and 70% dark energy. According to this picture, the vast majority of our universe consists of two exotic entities: dark matter and dark energy. They are the main constituents of the universe. The former is a form of matter that can clump, but which does not support sound waves; the latter is an energy density associated with empty space, which causes a tendency for the expansion of the universe to accelerate [Massimi, Peacock, 2014b, p. 33].

In respect to the concordance model, philosophers are disputing the inderdetermination problem. This model is not just empirically supported by direct empirical evidence that we may be able to find one day about dark energy and dark matter. It is embedded into a larger theoretical framework, which is general relativity. In so doing, the model receives indirect empirical support from any other piece of evidence that is a consequence of the larger theoretical framework within which the model is embedded [Ibid].

There have been proposed several **solutions to the major philosophical and methodological problems of cosmology**. The first above-mentioned methodological problem in cosmology is how we can extrapolate from our current laws of nature, to the early universe. To address this problem, the mathematician and cosmologist Hermann Bondi and other defenders of the so-called steady-state universe back in the 1950s, introduced what they called the *Perfect Cosmological Principle*, which says that the universe is homogeneous in its physical laws. However, the steady-state universe, within which that Principle was formulated, has long been disproved by experimental evidence for an evolving universe, coming from the discovery of cosmic microwave background.

The problem remains pressing, and has prompted philosophers and physicists to rethink the notion of laws in cosmology. One of the examples is the conception of the American physicist Lee Smolin who has introduced the view called '*Cosmological natural selection*'. He assumes that we should stop thinking the laws of nature are timeless and eternal, and embrace the view that laws have evolved with our universe. Thus, if we adopt cosmological natural selection, the problem of laws of nature disappears. Our universe is governed by our current laws of physics, which have exactly evolved with us and our universe [Smolin, 1997].

The second above-mentioned problem with cosmology is the uniqueness of its object of study and the specific problem that this poses for the testability of cosmology. Scientists have only our universe to study, and no other objects to compare it with. Karl Popper's *criterion of falsification* seems to offer a solution here. Popper believed that the method of science consisted in a deductive method, whereby given a hypothesis or conjecture with risky novel predictions, scientists can go about and search for one single piece of negative evidence, that can potentially falsify the hypothesis. If falsification is indeed the method of science, the uniqueness of our universe does not pose any obstacle for cosmology. All that is required from cosmology is one single risky prediction, which may be tested and proved wrong, what Popper called a potential falsifier.

Coming to the third methodological problem of the restricted access to what we can observe in terms of the past light-cone of the Earth now, the main problem that we face here, is a form of **indeterminism about spacetime**. There might be observationally indistinguishable spacetimes, namely many different models of spacetime, which are all compatible with the same past light-cone of events, so that locally, an observer looking at their past light-cone of events may not be able to tell in which of these different space-time models he or she actually lives. John Norton, an American historian and philosopher of science, illustrates the problem by comparing people with ants on an infinite flat Euclidean sheet of paper, who can survey only around a 10,000 square foot patch. We are not able to tell whether the spacetime we inhabit, is indeed infinitely flat or curved. Any inductive inference from available data to the exact nature of the space-time we live in is inevitably unjustified [Norton, 2011].

A crucial and highly disputable philosophical problem is the possibility of existence of the so-called '**anthropic principle'** and its justification. The term 'anthropic principle' was coined by Australian physicist *Brandon Carter* and first appeared in 1973. The key idea is that the kind of observer we are will set restrictions on the kind of physical conditions that we are likely to observe. We are physically based observers, and require very complicated internal structures, internal organs, and internal chemistry. Creatures like ourselves are only going to be found in places where the right sorts of conditions will be found to obtain. We are context-sensitive observers, and we will not be arranged randomly in space and time.

This principle is actually the philosophic consideration that <u>the physical universe must be compatible with the conscious life that observes it</u>. The anthropic principle is sometimes used to explain why the universe has the age and fundamental physical constants necessary for conscious life to originate and develop. The anthropic principle, in fact, has been applied to several distinct ideas, and this has contributed to some confusion and controversy over it [Halvorson, Kragh, 2013]. Nevertheless, all versions of the principle are often criticized for lacking falsifiability.

As for the diverse variants of the principle, besides B. Carter's conception, some other famous work on it was written by *John Barrow* and *Frank Tipler* ('The Anthropic Cosmological Principle', 1986). One of their hypotheses says that observers are necessary to bring the universe into being. The anthropic principle is used to explain the structure of the physical universe as created intentionally according to a plan which was to generate observers like us who require a very narrow range of physical conditions, but a very wide range of physical elements, and some of them (the heavier elements) are only formed in the heart of stars, the process of stellar nucleosynthesis.

The range of anthropic effects may suggest that the universe we inhabit is actually just a very small fraction of a much larger ensemble. Many philosophical and physical theories postulate that the universe we inhabit is one aspect of an enormously larger ensemble of worlds sometimes known as a **multiverse**. It can contain all the physically possible ways. The multiverse can be <u>all the physically possible combinations of conditions and forces</u>. If that is true, then we inhabit a universe that contains just the right combination of conditions necessary for our survival [Carr, Ellis, 2008]. Thus, we should give serious consideration to the existence of other universes with different values of the ‘fundamental parameters’.

Unit 8. Philosophical problems of chemistry

Philosophy of chemistry considers the methodology and underlying assumptions of chemistry. Philosophical problems of chemistry include such issues as:

• the relationship between chemical concepts and reality, e.g. the reality of concepts such as nucleophiles and electrophiles which has been questioned;

• questions regarding whether chemistry studies atoms (substances) or reactions (processes);

• symmetry in chemistry;

• reductionism with respect to physics and questions regarding whether quantum mechanics can fully explain all chemical phenomena.

• the fundamental limits to chemical knowledge.

It would seem that philosophy of chemistry emerged only recently. For much of its history, philosophy of science has been dominated by the philosophy of physics, but the philosophical problems of chemistry have received increasing attention since the latter part of the 20^{th} century. Among **contemporary philosophers of chemistry** there should be noted the Dutch philosopher *Jaap van Brake*, Maltese philosopher-chemist *Eric Scerri*, the German philosopher-chemist *Joachim Schummer*.

However, these philosophical topics themselves have a much longer history. One could even argue that ancient *Greek natural philosophy* started with profoundly chemical questions about the elemental constitution of the world and about how to provide reason to the sheer unlimited material variety and its amazing changes. How, for instance, water becomes solid or gaseous; wood turns into fire, smoke, and ashes, etc.? In fact, there is an almost continuous philosophical tradition focused on such questions. It is not surprising that the precursor of modern chemistry was *Aristotle* who studied the problems of the nature of substances and their transformations.

Major philosophical questions arise when one attempts to define chemistry and what it studies. Based on this, one of the crucial philosophical problems is **what chemistry is about**. What is its specific subject matter that distinguishes chemistry from other sciences? According to the *dictionary definitions*, chemistry is about substances, chemical reactions, molecules, and atoms. The questions remain what a substance, a chemical reaction, a molecule, and an atom are, and how these concepts relate to each other. Additionally, chemists frequently use non-existent chemical entities like resonance structures to explain the structure and reactions of different substances [Schummer, 2010: p. 165].

Unlike substances in philosophy, **a chemical substance** is a piece of matter of any size, form, and state of aggregation with clearly defined and unique chemical properties that are qualitatively different from the chemical properties of other substances. A chemical property of a substance is its ability to change into other substances under certain conditions, and such changes from one substance to another are called chemical reactions.

The fact that a substance is defined through its specific chemical reactions and a chemical reaction is defined through the specific substances involved, makes one end up in circular definitions: reactions define substances and substances define reactions. Can we escape the circle by giving priority to either substances or reactions? Thus, the question of what chemistry is about turns out to be not so easy. It prompts us to decide between two opposing philosophical traditions, **substance and process approaches**. A related philosophical problem is whether chemistry is the study of substances or reactions [Schummer, 2010: p. 166].

Substance proponents claim priority to entities, things, or substances and consider changes, like motion in space, to be only secondary attributes of entities. A chemical reaction here is defined by the change of certain substances. However in chemistry, change is essential rather than secondary; and it is radical because through chemical reactions all properties radically change. This suggests that *process approach* (where a substance is defined by its characteristic chemical reactions) would be more adequate here, because it considers entities only as temporary states. Moreover, process philosophers can point to the fact that in the natural world there are no fixed and isolated chemical substances but only permanent chemical change of matter [Ibid].

However, in order to describe these changes precisely we need concepts that grasp the various states of change, for which the concept of chemical substances appears to be most adequate. Chemists are inclined to solve the puzzle in a following way. As process philosophy correctly says, there are no fixed and isolated chemical substances in the natural world, but only in the laboratory conditions. The material world is thus adjusted to the conceptual needs. Yet, the experiment works only through a quasi-operational definition of chemical substances, according to which a chemical substance is the result of perfect purification, which includes thermodynamic operations such as distillation. Thus, substances are characterized through combination of both aspects of substance and process philosophies [Ibid].

As for atoms and molecules, usually these are widely conceived as the true microscopic components of all materials, that is why many argue that chemistry is ultimately about atoms and molecules rather than about substances. Investigating substances and chemical reactions is only a means to develop a better understanding of atoms and molecules and their reconfigurations that we perceive as chemical change. On the other hand, one could argue that all our knowledge about atoms and molecules is only a means to better understand and then explain and predict the chemical behavior of substances [Schummer, 2010: p. 167].

There are differing positions on the question of in what way one explains the means and ends of chemistry. The first position (which one might call **theoreticism**) takes the knowledge of substances as means for the knowledge of atoms and molecules to be considered an end in itself. For the second position (**experimentalism**) the knowledge of atoms and molecules is only a theoretical means for the proper end of understanding the behavior of substances. Since substances are artificially produced in the laboratory for our conceptual needs, one can also assume a third position, which one might call realism because it acknowledges a fundamental difference between our concepts and the world. This position takes our knowledge of substances only as a means to develop a better understanding of our messy material world [Schummer, 2010: p. 168].

Indeed, the **concept of molecules** works only for certain substances <u>as a useful model approximation</u>. This model works quite well with many organic substances and gases but fails for instance with simple substances like water, metals, or salts for most purposes. Hence, rather than talking of molecules, a more generic concept is that of interatomic structures of substances. Interatomic structures of substances are dynamic entities, even if we disregard quantum mechanics for the sake of simplicity. To take water as an example, the structure continuously changes on a time scale of less than a trillionth of a second [Schummer, 2010: p. 168-169].

Theoreticism is confronted with severe conceptual problems. It lacks useful concepts of kinds, both for entities and processes. If such concepts are introduced by virtue of model approximations, theoreticism would have to concede that chemistry is ultimately about its own models about the world rather than about the material world itself, i.e. only about what theoreticians are doing. However, experimentalism turns out to feel too self-satisfied because it creates and focuses on the laboratory systems that best fit its conceptual framework. If the goal of science is to understand the world that we all live in, then realism may become more viable position, such that theoretical and experimental laboratory investigations are only useful means to that end [Schummer, 2010: p. 169].

Philosophers of chemistry discuss issues of <u>**symmetry and chirality**</u> in nature. Organic (i.e., carbon-based) molecules are most often chiral. Amino acids, nucleic acids and sugars are the basic chemical units of life. Philosophers discuss facts regarding the origins of the phenomenon of homochirality, namely whether it emerged contingently. Some speculate that answers can be found in comparison to extraterrestrial life, if it is ever found. Other philosophers question whether there exists a bias toward assumptions of nature as symmetrical, thereby causing resistance to any evidence to the contrary.

Another problem sounds like "**Is chemistry reducible to physics**?". This issue has been vividly debated. The debate was originally inspired by older bold claims like that of the mathematician Paul Dirac in 1929, according to whom the whole of chemistry would be reducible to quantum mechanics and thus would be part of physics. Such claims belong to the general position of physicalism, according to which physics would be fundamental to any science, including biology, the social sciences, and psychology. If this is a metaphysical worldview, then it is beyond the scope of philosophy of chemistry. If the claim is about the explanatory and predictive scope of a specific theory, it is up to scientists rather than to philosophers to assess the exact limits of the theory by checking the thesis against experimental findings and rejecting unfounded claims according to established scientific standards. The remaining job of philosophers – both of chemistry and physics, because the reductionist claim is about the relation between chemistry and physics – largely consists in clarifying the underlying concepts and in checking for hidden assumptions [Schummer, 2010: p. 170].

Metaphysical or ontological reductionism claims that the supposed objects of chemistry are actually the objects of quantum mechanics and that quantum mechanical laws govern their relations. Epistemological or theory reductionism claims that all theories, laws, and fundamental concepts of chemistry can be derived from quantum mechanics as more basic and more comprehensive. Methodological reductionism recommends applying quantum mechanical methods to all chemical problems, because that would be the most successful approach in the long run [Ibid].

The discussion of reductionism distracts from the fact that chemistry and physics have historically closely developed with many fruitful interdisciplinary exchanges without giving up their specific disciplinary foci. For instance, chemistry greatly benefits from quantum mechanics, because that is the only theory through which scientists have to explain electromagnetic, mechanical, and thermodynamic properties of materials. However, when it comes to chemical properties, the properties that define chemical substances and which chemists are mostly interested in, quantum mechanics is extremely poor such that chemists here rely almost exclusively on chemical structure theory. Rather than focusing on reductionism, with its underlying notion of a Theory of Everything, it seems more useful to discuss the strengths and weaknesses of different theories for different purposes [Schummer, 2010: p. 172].

An important philosophical problem of chemistry is connected with the **fundamental limits to chemical knowledge**. Again, it is up to scientists to check the limits of a specific theory or model. The epistemological task consists in scrutinizing a scientific approach, its concepts and methods. In this respect, the problem of the limits of chemical knowledge includes such things as the concept of pure substances and methodological pluralism [Schummer, 2010: p. 174].

Chemical substances are idealizations in two regards that each pose limits to chemical knowledge. First, although chemical substances are experimentally produced through purification techniques and as such are real entities, perfect purity is a conceptual ideal that can never be fully reached in practice. Secondly, and more importantly, the pure substances that chemists produce and put in bottles for chemical investigations do not exist outside the laboratory. Instead, the materials outside the laboratory are messy and mostly under continuous transformations and flux. Hence, the conceptual framework of chemistry is not very suitable to describe the real material world, but still it is the best we have for that purpose [Schummer, 2010: p. 174-175].

As for methodological pluralism, it requires that the quality of a model is not judged by standards of truth and universality but, instead, by its usefulness and the precision by which its scope of applications is limited. Methodological pluralism produces a kind of patchwork knowledge rather than universal knowledge. The advantage is that it allows incorporating new kinds of knowledge without fundamental crisis by extending the patchwork. Moreover, it can deal with relevance aspects, which the claim to universal knowledge cannot [Schummer, 2010: p. 176].

In conclusion, it should be noted that, first, chemistry is essentially about radical change that cannot adequately be captured by physics. Since radical change enables unlimited synthesis, chemical knowledge is fundamentally incomplete. Second, chemistry deals with real-world complexity by adjusting the material world in the laboratory to its classificatory concepts, which are not reducible to physics, and by following methodological pluralism, both of which pose limits to understanding the world outside the laboratory, including predictions of how its synthetic products behave in that world. On the whole, much of current philosophy of chemistry is still in a process of defining itself anew.

Unit 9. Philosophical problems of biology and neurobiology

The philosophy of biology deals with epistemological, methodological, and ethical issues in the biological and biomedical sciences. Philosophers generally have long been interested in biology (e.g., Aristotle, Descartes, Kant, etc.), but philosophy of biology only emerged as an independent field in the 1960s and 1970s [Haber, Hamilton, Okasha, Odenbaugh, 2010: p. 184]. Biology began receiving increasing attention from philosophers of science from the rise of Neodarwinism in the 1930s and 1940s to the discovery of the structure of DNA in 1953 to more recent advances in genetic engineering. Besides the theory of evolution and the issues of natural selection, the significant philosophical ideas of biology include the reduction of all life processes to biochemical reactions, the problems of altruism, the problems of neurobiology in a broader context of neuroscience, etc.

The first issue to be discussed is **what the biological sciences are**. They are as diverse as the physical sciences in respect to the systems they study, the methods they employ, and the standards of explanations of their phenomena. For instance, the theoretical contexts and practices of molecular genetics are very different from those of comparative morphology. Thus, it is difficult to characterize all of biology in a meaningful way. Several of the biological sciences, including population genetics, epidemiology, and ecosystem ecology, enjoy rich traditions of formal modeling while others are comparative and still others are experimental [Haber, Hamilton, Okasha, Odenbaugh, 2010: p. 185-186].

It should be noted that one of the widespread tendencies in biology includes quantitative approaches to biological systems, such as game-theoretical and multi-level approaches to natural selection, or differential equations to population dynamics, as well as very new quantitative approaches to ecosystem ecology and to allometry and metabolic scaling. Formal models have been crucial to the development of biology, and have issued in some simple, general statements about the biological world. Biologists and philosophers of biology have therefore continued to ask whether there are laws of biology, and how these might compare with laws of physics. Others have asked whether the models mean abstract and highly idealized models, and if so, what the appropriate relationship between the model and the world is [Haber, Hamilton, Okasha, Odenbaugh, 2010: p. 186-187].

One of the sciences most responsible for describing the diversity of the living world, understanding its patterns, and discovering the historical and hierarchical relations between organisms and taxa, is **systematics**. Its two major goals are (1) to discover and describe species and (2) to determine the phylogenetic relationships of these species. As systematics primarily focuses on the pattern of evolution, it cannot do without discussing positions which are inherently philosophical in nature. In order to discover species, systematics must have some idea of what it is to be a species. This is not only a biological question, but a deeply philosophical one as well.

Determining the phylogenetic, or genealogical, relationships between groups of species requires making an inference about the distant past that is not directly observable. This challenge is both metaphysical and epistemological in nature [Haber, Hamilton, Okasha, Odenbaugh, 2010: p. 187-188].

For a long time, **species** were taken to be exemplars of natural kinds by philosophers. Now, however, it has been recognized that things are not so simple. What this means is a classic example of a philosophy of biology problem. This characterization of species is at odds with Darwinian thinking. That is, evolutionary theory requires dynamics that the natural-kind view denies. With respect to this, a more adequate conception of species is the individuality thesis which says that particular species are best understood as individuals. This means that species are best understood as having parts, and that species are historical entities, which is to say that they exist in space and time, rather than abstractly [Haber, Hamilton, Okasha, Odenbaugh, 2010: p. 188-189].

Biologists turned out to be generally receptive to the individuality thesis, while philosophers have been more resistant to it, and even nowadays, one can find a criticism from their side. Partly this is due to historical inertia, as philosophers have often characterized species as exemplars of natural kinds, and the individuality thesis presents a serious challenge to this useful characterization. In the context of this thesis, there exist some other debates, such as the species problem which is what kinds of groups of organisms ought to count as being species. Are species groups of organisms or groups of populations, or parts of time-extended lineages (of populations, organisms, or some other genealogical group)? Given space constraints, this problem has two major competing answers: the biological species concept (BSC) and the phylogenetic species concept (PSC) [Haber, Hamilton, Okasha, Odenbaugh, 2010: p. 189-190].

A crucial epistemological issue here is a **phylogenetic inference**. Phylogeny is the pattern of common descent and is usually represented by phylogenetic trees. Discovering phylogenies presents a problem familiar to philosophers of science – a special case of the problem of underdetermination of theory by evidence. Furthermore, deep evolutionary history cannot be directly observed, and all of these possible trees are consistent with the data used to infer this history. The challenge facing systematics is twofold: whether phylogenetic inference may be justified in light of such epistemic challenges, and which methods of phylogeny reconstruction allow such justification. There is a consensus between philosophers and biologists on the first issue: inferring phylogeny is a legitimate task in modern systematic [Haber, Hamilton, Okasha, Odenbaugh, 2010: p. 191-192]. However, the question of inferential methods to provide a justified account of phylogeny is still debatable.

Another significant problem in biology is a **level of selection**. Traditionally, *Darwinians* have understood selection as acting primarily at the level of the organism. For them, it is the differential survival and reproduction of individual organisms that drives the evolutionary process. There are alternative views, however. Advocates of *group selection* argue that groups of organisms, rather than individual organisms, may sometimes function as levels of selection; "*genic selectionists*" such as Richard Dawkins argue that the true level of selection is in fact the gene; while proponents of *multi-level selection* (e.g. E. Wilson) argue that natural selection can occur simultaneously at more than one hierarchical level. Thus, the problem has invoked such question as "Does natural selection act on organisms, genes, groups, colonies, demes, species, or some combination of these?" [Haber, Hamilton, Okasha, Odenbaugh, 2010: p. 201-202].

A crucial problem within philosophy of biology deals with the relationship between **reductionism and holism**. It has both epistemological and methodological significance, as well as ethical and metaphysical connotations. According to *reductionism*, higher-level biological processes reduce to physical and chemical processes. For instance, the biological process of respiration is explained as a biochemical process involving oxygen and carbon dioxide. By contrast, *holism* is the view that emphasizes higher-level processes, also called emergent properties, namely, phenomena at a larger level that occur due to the pattern of interactions between the elements of a system over time. As individual organisms must be understood in the context of their ecosystems, a question arises of whether lower-level biological processes must be understood in the broader context of the living organism in which they take part [Rosenberg, McShea, 2008: p. 96-98]. With respect to the problem discussed, another conception should be noted which is **vitalism**. This is a view that there is a life-force that gives living organisms their life and acts with purposes according to its pre-established form. However, it is unmeasurable scientifically and has been rejected by mainstream biologists since the 19th century.

Debates over the empirical facts and what they might mean has been intimately bound up with the **problem of altruism**, because altruism is a very clear case in which the level of selection really matters for understanding and explaining the biological world and for evaluating the quality of present evolutionary theory. In evolutionary biology, "altruism" refers to any behavior that is costly to the individual performing the behavior, but benefits others, where the costs and benefits are measured in number of offspring, the units of reproductive fitness. Altruism in this sense is common in nature, particularly among animals living in social groups, but it is hard to see how it could have evolved by natural selection acting on organisms. By definition, an animal that behaves altruistically will secure fewer resources and have fewer offspring than its selfish counterparts, and so will be selected against. Thus, a question arises of how, then, altruistic behavior could have evolved by a selective process that should eliminate it [Haber, Hamilton, Okasha, Odenbaugh, 2010: p. 203].

One solution to this puzzle, first suggested by Darwin in his *Descent of Man* (1871), is that altruism can evolve by selection at the group level. It is possible that groups containing many altruists will out-reproduce groups containing mainly selfish organisms, even though within any group, altruists do worse. In principle, altruism and other group-beneficial behaviors might evolve by natural selection acting on groups, rather than organisms. Some theorists hold that kin selection, far from being an alternative to group selection, is in fact a version of group selection, expressed in different language and using different mathematical models. However, kin selection can only explain the existence of altruism directed towards relatives, but there are well studied cases of unrelated organisms forming cooperative groups of varying degrees of integration. Some recent theorists have stressed that individual organisms are themselves groups of cooperating cells, while each cell is a group of cooperating sub-units, including organelles, chromosomes and genes. Since cells and multi-celled organisms clearly have evolved, with sub-units that work for the good of the group, group selection ought to be of importance in the history of life. There are empirical studies conducted in this context. Yet, it is often not clear what these studies mean for the debate. As Dawkins demonstrated in *The Selfish Gene* (1976), it is hard to see what facts might establish that one or the other interpretation is correct [Haber, Hamilton, Okasha, Odenbaugh, 2010: p. 203-205].

The conclusion may be that biologists cannot explain the persistence of individual traits of altruism, cooperation, or other fitness-reducing actions operating on units larger rather that reproducing individual organisms. According to **genocentrism**, an approach, advanced by **Richard Dawkins**, the only real subject of selection, its real target and interactor is the gene, which is the cause of development, for both individuals and groups. Compared to organisms, genes are forever, or at least their DNA sequences are almost perfectly copied over and over again. It let us think of organisms as mere extensions of the genes. It means that cells, organs, organisms, and groups have no ultimate explanatory role in evolutionary biology. Such a proposal outraged biologists, philosophers, and social scientists. One aspect of criticism was "*genetic determinism*" it seemed to encourage, including the moral side of it: genocentrism means that socially significant traits are somehow fixed by the genes, and cannot be modified much by changes in the social environment. This view is also discussed in the context of the question that can be put as such: Does evolution have any goal or purpose, perhaps one that might give our existence meaning or intelligibility? [Rosenberg, McShea, 2008: p. 157-166]

The aforesaid brings us to another controversy which is connected with the **influence of biology on the social sciences** and the claim of biology to answer the questions of moral and political philosophy. Evolutionary biology in particular has often inspired, at least since Darwin's day, a hope of putting ethics on a "scientific" footing. Darwin's evolutionary theory does not only explain the common descent of all organisms on earth, but also identifies a causal process that produces the adaptations in the nature. Although his theory does not attain the standards of accurate prediction and detailed explanation that theories in physics and chemistry do, it is potentially far more relevant to questions about ourselves. Some still consider the biological understanding as finally providing the basis for an enduring moral concern for all living things and the planet of Earth.

Besides biological and cultural anthropology, such disciplines as sociology, psychology, even economics and politics have left influence of Darwinism. Biologically inspired research programs in the social sciences have been given new impetus since the publication of **E.O. Wilson's** *Sociobiology: The New Synthesis* (1975). From the time of Darwin's 'The Descent of Man' until the publication of Wilson's book, much social science generally resisted Darwinian approach. First, it was difficult to explain the learned behavior of humans by means of random variation and natural selection. Second, fieldwork by cultural anthropologists in the first part of the 20th century suggested a different explanation. Third, the evolutionary mechanism implies the production of organisms designed to maximize individual fitness, and human sociality, cultural norms, and social institutions all require cooperation, trust, unselfishness, and other fitness-reducing behaviors that should condemn the species who acts this way to extinction.

Wilson's **sociobiology** as the "systematic study of the biological basis of all social behavior" [Wilson, 1975: p. 4] quickly became the subject of violent controversy. The first meaning of "sociobiology" as applied to Wilson's original project is referred to as behavioral ecology. This is a scientific discipline that uses evolutionary theory and especially adaptationist methods to try to understand animal behavior. The term 'sociobiology" is also occasionally used to refer to current evolutionary approaches to human behavior. They keep Wilson's original behavioral focus but demonstrate a variety of theoretical and methodological features of their own. Among them, there is evolutionary psychology, advanced first by Leda Cosmides and John Tooby in their *The Psychological Foundations of Culture* (1992). On this view, the brain is composed of functionally specialized modules, each of which evolved separately [Downes, 2014].

One of the significant problems for an <u>evolutionary theory of culture</u> is the question of replicators, which are units that accurately copy themselves. In biology, genes play this role. Some proponents of cultural evolution have introduced a concept explicitly modeled on the gene – <u>the meme</u>, introduced by Dawkins in his 'The Selfish Gene' as a unit of cultural transmission [Dawkins, 2006]. Roughly, a meme is something in the brain that causes behaviors, or some features of behaviors, and this is contagious and copied in other brains, e.g. bird songs copied from generation to generation being critical to fitness. In human culture, a meme can be ideas, thoughts, beliefs, desires, mental images, formulae, theories, etc. (e.g. an idea about how to dress, which results in other dressing that way and becomes a fashion). However, to provide the basis for a Darwinian theory of cultural evolution, memes must replicate accurately. Without the confidence about replication and reproduction, we have to think of memetic evolution as a mere metaphor [Lewens, 2013]. Thus, such evolutionary-oriented view, along with others applied to the human culture and sociality, continue to be the subject of fierce debates.

Over the past three decades, philosophy of science has grown increasingly "local" in the sense that it has switched its focus from general features of scientific practice to puzzles, issues, and concepts specific to particular disciplines. One of the examples is **philosophy of neuroscience**. The group of disciplines with a common focus on the brain and nervous system has come to be known collectively as "the neurosciences" or just "neuroscience." These scientific fields have benefited from the biological achievements in the latter half of the 20th century. There is a growing number of philosophers who are interested in applying the findings of neuroscience to a variety of questions in the philosophy of mind, epistemology, etc. The literature distinguishes "philosophy of neuroscience" and "neurophilosophy". The former concerns foundational issues internal to neuroscience itself. The latter concerns application of neuroscientific concepts to traditional philosophical questions. However taken broadly, philosophy of neuroscience deals with any philosophical investigation where neuroscience plays an important role [Bickle, Mandik, Landreth, 2012].

One of the significant problems within this field is to understand its scope. Neuroscience is governed by a few global frameworks – *physicalism* (the view that everything is physical) and perhaps, to some extent, *computationalism* (the view that reduces mental states to computational ones) – borrowed from other fields and applied to nervous systems. They serve as guiding assumptions rather than theories. It leads to think that philosophy of neuroscience lacks a broad theoretical foundation comparable to that of philosophy of physics or biology. Nevertheless, neuroscience is a data-rich discipline, and on the basis of this factual knowledge, has developed a lot of local explanations or domain-restricted theories. Besides, the list of articulated local models here is also extensive. Neuroscientists know neurons integrate inputs from other neurons and what causes them to fire; how synaptic connections are strengthened; and how this process may be involved in learning and memory. They have a rough understanding of how visual processing works and which brain areas are involved in a number of higher cognitive functions. Yet theoretical understanding remains fractional. This makes it disputable whether a philosophy of neuroscience can be as a field without a broad theory. However, as some authors put it, if the philosophy of neuroscience did not exist, "it would be necessary to invent it" [Gold, Roskies, 2008: p. 375].

Another aspect of how neuroscience is especially interesting to philosophers is the issue of the correct level of explanation to seek in understanding brain function. Is it right to think of the **brain as a computing device**? This is a domain of computational neuroscience. The answers to the question actually depend on how one define a *computation*. Pancomputationalism is the view that everything can be said to compute. The most common view, however, is the semantic account of computation which requires that there is no computation without representation, as Jerry A. Fodor puts it in his *Language and Thought* (1975). It should be noted that the findings of neuroscience have impacted philosophical debates about the nature of consciousness and its relation to physical mechanisms. However, any possible brain-process account of consciousness cannot really explain how and why that particular brain process causes conscious experience. This makes some think that we will probably never get a complete explanation of consciousness at the level of neural mechanism [Bickle, Mandik, Landreth, 2012].

Neuroscience plays a very important role in understanding the **nature of cognition**. There even exists a view, though very arguable, that all mental phenomena can ultimately be represented in the language of neuroscience, or alternatively, in the terms of brain phenomena. In any case, advances in this field may have the potential to influence our approach to a number of epistemological questions, including those regarding the nature of knowledge and belief, the justification of belief, and the roles of reason and emotion in grounding knowledge. Neuroscience has also contributed to moral philosophy and even given rise to an area which has been termed "neuroethics." It comprises two related fields of study. One concerns the ethical, legal and social impact of neuroscience, including the ways in which neurotechnology can be used to predict or alter human behavior [Bickle, Mandik, Landreth, 2012]. To some extent, the content of this area is not fundamentally different from that of bioethics which is the study of the controversial ethical challenges emerging from the new context caused by advances in biology and medicine (e.g. the use of biotechnologies). The other field of neuroethics deals with such philosophical problems as the nature of free will, moral responsibility, personal identity, etc.

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