**Philosophy of science**

**Philosophy of science** is a branch of [philosophy](http://en.wikipedia.org/wiki/Philosophy) concerned with the foundations, [methods](http://en.wikipedia.org/wiki/Scientific_method), and implications of [science](http://en.wikipedia.org/wiki/Science). This discipline sometimes overlaps [metaphysics](http://en.wikipedia.org/wiki/Metaphysics), [ontology](http://en.wikipedia.org/wiki/Ontology) and[epistemology](http://en.wikipedia.org/wiki/Epistemology), for example, when it explores whether scientific results comprise a study of [truth](http://en.wikipedia.org/wiki/Truth). In addition to these central problems of science as a whole, many [philosophers](http://en.wikipedia.org/wiki/Philosopher) of science consider problems that apply to particular sciences (e.g. [philosophy of biology](http://en.wikipedia.org/wiki/Philosophy_of_biology) or [philosophy of physics](http://en.wikipedia.org/wiki/Philosophy_of_physics)). Some philosophers of science also use contemporary results in science to reach conclusions about philosophy.

Philosophy of science has historically been met with mixed response from the [scientific community](http://en.wikipedia.org/wiki/Scientific_community). Though scientists often contribute to the field, many prominent scientists have felt that the practical effect on their work is limited.

### What counts as science?

Should [psychoanalysis](http://en.wikipedia.org/wiki/Psychoanalysis) be considered science? How about [creation science](http://en.wikipedia.org/wiki/Creation_science) or the [inflationary multiverse](http://en.wikipedia.org/wiki/Multiverse) hypothesis? Distinguishing between science and non-science (including [pseudoscience](http://en.wikipedia.org/wiki/Pseudoscience)) is referred to as the demarcation problem. [Karl Popper](http://en.wikipedia.org/wiki/Karl_Popper) called this the central question in the philosophy of science.[[1]](http://en.wikipedia.org/wiki/Philosophy_of_science#cite_note-Thornton2006-1) However, no unified account of the problem has won acceptance among philosophers, and some regard the problem as unsolvable or uninteresting.[[2]](http://en.wikipedia.org/wiki/Philosophy_of_science#cite_note-Laudan1983-2)

Early attempts by the [logical positivists](http://en.wikipedia.org/wiki/Logical_positivists) grounded science in observation while non-science was non-observational and hence meaningless.[[3]](http://en.wikipedia.org/wiki/Philosophy_of_science#cite_note-Uebel2006-3) Popper argued that the central property of science is [falsifiability](http://en.wikipedia.org/wiki/Falsifiability) (i.e., all scientific claims can be proven false, at least in principle, and if no such proof can be found despite sufficient effort then the claim is likely true).

#### Scientific explanation

In addition to providing predictions about future events, society often takes scientific theories to offer [explanations](http://en.wikipedia.org/wiki/Explanation) for events that occur regularly or have already occurred. Philosophers have investigated the criteria by which a scientific theory can be said to have successfully explained a phenomenon, as well as what gives a scientific theory [explanatory power](http://en.wikipedia.org/wiki/Explanatory_power). One early and influential theory of scientific explanation was put forward by [Carl G. Hempel](http://en.wikipedia.org/wiki/Carl_Gustav_Hempel) and [Paul Oppenheim](http://en.wikipedia.org/wiki/Paul_Oppenheim) in 1948. Their [Deductive-Nomological](http://en.wikipedia.org/wiki/Deductive-Nomological) (D-N) model of explanation says that a scientific explanation succeeds by subsuming a phenomenon under a minor law. An explanation, then, is a valid deductive argument. For empiricists like Hempel and other logical positivists, this provided a way of understanding explanation without appeal to causation.[[5]](http://en.wikipedia.org/wiki/Philosophy_of_science#cite_note-Hempel1948-5) Although ignored for a decade, this view was subjected to substantial criticism, resulting in several widely believed counter examples to the theory.[[6]](http://en.wikipedia.org/wiki/Philosophy_of_science#cite_note-Salmon1992-6)

In addition to their D-N model, Hempel and Oppenheim offered other statistical models of explanation which would account for [statistical sciences](http://en.wikipedia.org/wiki/Statistical_sciences).[[5]](http://en.wikipedia.org/wiki/Philosophy_of_science#cite_note-Hempel1948-5) These theories have received criticism as well.[[6]](http://en.wikipedia.org/wiki/Philosophy_of_science#cite_note-Salmon1992-6) [Wesley Salmon](http://en.wikipedia.org/wiki/Wesley_C._Salmon) attempted to provide an alternative account for some of the problems with Hempel and Oppenheim's model by developing his statistical relevance model.[[7]](http://en.wikipedia.org/wiki/Philosophy_of_science#cite_note-Salmon1971-7)[[8]](http://en.wikipedia.org/wiki/Philosophy_of_science#cite_note-Woodward2003-8) In addition to Salmon's model, others have suggested that explanation is primarily motivated by unifying disparate phenomena or primarily motivated by providing the causal or mechanical histories leading up to the phenomenon (or phenomena of that type)

#### Empirical verification

Science relies on evidence to [validate](http://en.wikipedia.org/wiki/Validity) its theories and models, and the predictions implied by those theories and models should be in agreement with [observation](http://en.wikipedia.org/wiki/Observation). Ultimately, observations reduce to those made by the unaided human senses: sight, hearing, etc. To be accepted by most scientists, several impartial, competent observers should agree on what is observed. Observations should be repeatable, e.g., experiments that generate relevant observations can be (and, if important, usually will be) done again. Furthermore, predictions should be specific; one should be able to describe a possible observation that would [falsify](http://en.wikipedia.org/wiki/Falsifiability) the theory or a model that implies the prediction.

Nevertheless, while the basic concept of empirical verification is simple, in practice, there are difficulties as described in the following sections.

#### Induction

Philosophers of science have asked how the laws of science, such as Newton's Third Law, can be justified? After all, it is not possible to have tested every possible instance in which a scientific law applies. In the case of Newton's Third Law, there have been many tests, and in each one a corresponding reaction has been found, but can one ever be sure that future tests will continue to support Newton's Third Law? One approach to justifying scientific laws and more generally inferring generalizations from instances is to use [induction](http://en.wikipedia.org/wiki/Inductive_reasoning). Using inductive reasoning, one reasons that if a situation holds in all *observed* cases, then the situation holds in *all* cases. Thus, by induction scientific laws and generalizations are inferred by observing a finite number of observations that conform to the law or generalization.

Explaining why people think induction produces knowledge has proven problematic. One cannot use [deduction](http://en.wikipedia.org/wiki/Deductive_reasoning), the usual process of moving logically from premise to conclusion, because there is no [syllogism](http://en.wikipedia.org/wiki/Syllogism) that allows this. Indeed, induction is sometimes mistaken; 17th century biologists observed many white [swans](http://en.wikipedia.org/wiki/Swan) and none of other colours, but not all swans are white. Similarly, it is at least conceivable that an observation will be made tomorrow that shows an occasion in which an action is not accompanied by a reaction; the same is true of any scientific statement.

One answer has been to conceive of a different form of rational argument, one that does not rely on deduction. Deduction allows one to formulate a specific truth from a general truth: all [crows](http://en.wikipedia.org/wiki/Crow) are black; this is a crow; therefore this is black. Induction somehow allows one to formulate a general truth from some series of specific observations: this is a crow and it is black; that is a crow and it is black; no crow has been seen that is not black; therefore all crows are black.

The [problem of induction](http://en.wikipedia.org/wiki/Problem_of_induction) is one of considerable debate and importance in the philosophy of science: is induction indeed justified, and if so, how?

#### Ockham's razor

The practice of scientific [inquiry](http://en.wikipedia.org/wiki/Inquiry) typically involves a number of [heuristic](http://en.wikipedia.org/wiki/Heuristic) principles, such as the principles of conceptual economy or theoretical [parsimony](http://en.wikipedia.org/wiki/Parsimony). These are customarily placed under the rubric of [Ockham's razor](http://en.wikipedia.org/wiki/Ockham%27s_razor), named after the 14th century Franciscan friar [William of Ockham](http://en.wikipedia.org/wiki/William_of_Ockham), who is credited with many different expressions of the maxim, not all of which have yet been found among his extant works.[[9]](http://en.wikipedia.org/wiki/Philosophy_of_science#cite_note-9)

As interpreted in contemporary scientific practice, "entities should not be multiplied beyond necessity" advises opting for the [simplest](http://en.wikipedia.org/wiki/Simplicity) theory among a set of competing theories that have a comparable explanatory power, discarding assumptions that do not improve the explanation. Among the many difficulties that arise in trying to apply Ockham's razor is the problem of formalizing and quantifying the "measure of simplicity" that is implied by the task of deciding which of several theories is the simplest. Although various measures of simplicity have been brought forward as potential candidates, it is generally accepted that there is no such thing as a theory-independent measure of simplicity. In other words, there appear to be as many different measures of simplicity as there are theories themselves, and the task of choosing between measures of simplicity appears to be every bit as problematic as the job of choosing between theories. Moreover, it is extremely difficult to identify the hypotheses or theories that have "comparable explanatory power", though it may be readily possible to rule out some of the extremes. Ockham's razor also does not say that the simplest account is to be preferred regardless of its capacity to explain outliers, exceptions, or other phenomena in question. The principle of falsifiability requires that any exception that can be reliably reproduced should invalidate the simplest theory, and that the next-simplest account which can actually incorporate the exception as part of the theory should then be preferred to the first. As [Albert Einstein](http://en.wikipedia.org/wiki/Einstein) puts it, "The supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience"

### Theory and observations

When making observations, scientists look through telescopes, study images on electronic screens, record meter readings, and so on. Generally, on a basic level, they can agree on what they see, e.g., the thermometer shows 37.9 degrees C. But, if these scientists have different ideas about the theories that have been developed to explain these basic observations, they can interpret them in different ways. Ancient scientists interpreted the rising of the Sun in the morning as evidence that the Sun moved. Later scientists deduced that the Earth is rotating. For example, if some scientists may conclude that certain observations confirm a specific hypothesis, skeptical colleagues may suspect that something is wrong with the test equipment. Observations when interpreted by a scientist's theories are said to be [theory-laden](http://en.wikipedia.org/wiki/Theory-laden).

Observation involves both [perception](http://en.wikipedia.org/wiki/Philosophy_of_perception) as well as [cognition](http://en.wikipedia.org/wiki/Cognitive_process). That is, one does not make an observation passively, but is also actively engaged in distinguishing the phenomenon being observed from surrounding sensory data. Therefore, observations are affected by our underlying understanding of the way in which the world functions, and that understanding may influence what is perceived, noticed, or deemed worthy of consideration. More importantly, most scientific observation must be done within a theoretical context in order to be useful. For example, when one observes a measured increase in temperature with a thermometer, that observation is based on assumptions about the nature of temperature and its measurement, as well as assumptions about how the thermometer functions. Such assumptions are necessary in order to obtain scientifically useful observations (such as, "the temperature increased by two degrees").

Empirical observation is used to determine the acceptability of [hypotheses](http://en.wikipedia.org/wiki/Hypothesis) within a theory. Justification of a hypothesis often includes reference to a theory – operational definitions and hypotheses – in which the observation is embedded. That is, the observation is framed in terms of the theory that also contains the hypothesis it is meant to verify or falsify (though of course the observation should not be based on an assumption of the truth or falsity of the hypothesis being tested). This means that the observation cannot serve as an entirely neutral arbiter between competing hypotheses, but can only arbitrate between hypotheses within the context of the underlying theory that explains the observation.

#### Objectivity of observations in science

t is vitally important for science that the [information](http://en.wikipedia.org/wiki/Information) about the surrounding world and the [objects](http://en.wikipedia.org/wiki/Object_%28philosophy%29) of study be as accurate and as reliable as possible. For the sake of this, [measurements](http://en.wikipedia.org/wiki/Measurement) which are the source of this information must be as [objective](http://en.wikipedia.org/wiki/Objectivity_%28science%29) as possible. Before the invention of [measuring tools](http://en.wikipedia.org/wiki/Measuring_tool) (like [weights](http://en.wikipedia.org/wiki/Weight), [meter](http://en.wikipedia.org/wiki/Meter) sticks, [clocks](http://en.wikipedia.org/wiki/Clock), etc.) the only source of information available to humans were their senses (vision, hearing, taste, tactile, sense of heat, sense of gravity, etc.). Because human senses differ from person to person (due to wide variations in personal chemistry, deficiencies, inherited flaws, etc.) there were no objective measurements before the invention of these tools. The consequence of this was the lack of a rigorous science.

With the advent of exchange of goods, [trades](http://en.wikipedia.org/wiki/Trade), and [agricultures](http://en.wikipedia.org/wiki/Agriculture) there arose a need for such measurements, and science (arithmetic, geometry, mechanics, etc.) based on standardized [units of measurements](http://en.wikipedia.org/wiki/Units_of_measurement) ([stadia](http://en.wikipedia.org/wiki/Stadia_%28length%29), [pounds](http://en.wikipedia.org/wiki/Pound_%28mass%29), [seconds](http://en.wikipedia.org/wiki/Second), etc.) was born. To further abstract from unreliable human senses and make measurements more objective, science uses measuring [devices](http://en.wikipedia.org/wiki/Measuring_instrument) (like spectrometers, voltmeters, interferometers, thermocouples, counters, etc.) and lately — computers. In most cases, the less human involvement in the measuring process, the more accurate and reliable scientific data are. Currently most measurements are done by a variety of mechanical and electronic sensors directly linked to computers—which further reduces the chance of human error/contamination of information. The current accuracy of measurement of mass is about 10−10, of angles—about 10−9, and of time and length intervals in many cases reaches the order of 10−13 - 10−15.[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia%3ACitation_needed)] This has made it possible to measure, say, the distance to the Moon with sub-centimeter accuracy (see [Lunar laser ranging experiment](http://en.wikipedia.org/wiki/Lunar_laser_ranging_experiment)), to measure slight movement of [tectonic plates](http://en.wikipedia.org/wiki/Tectonic_plates)using [GPS](http://en.wikipedia.org/wiki/GPS) with sub-millimeter accuracy, or even to measure as slight variations in the distance between two mirrors separated by several kilometers as 10−18 m—three orders of magnitude less than the size of a single atomic nucleus—see [LIGO](http://en.wikipedia.org/wiki/LIGO).

Another question about the objectivity of observations relates to the so-called ["experimenter's regress"](http://en.wikipedia.org/wiki/Experimenter%27s_regress), as well as to other problems identified from the [sociology of scientific knowledge](http://en.wikipedia.org/wiki/Sociology_of_scientific_knowledge): as with all forms of human reasoning, the people who interpret the observations or experiments always have cognitive and social biases that lead them, often in an unconscious way, to introduce their own interpretations into their description of what they are 'seeing'. Some of these arguments can be shown to be of a limited scope, when examined from a [game-theoretic](http://www.uned.es/dpto_log/jpzb/abstracts.html#Rhetoric,_induction,_and_the_free_speech_dilemma._) point of view.

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Philosophy and Science

The touchstone of the value of philosophy as a world-view and methodology is the degree to which it is interconnected with life. This interconnection may be both direct and indirect, through the whole system of culture, through science, art, morality, religion, law, and politics. As a special form of social consciousness, constantly interacting with all its other forms, philosophy is their general theoretical substantiation and interpretation.

Can philosophy develop by itself, without the support of science? Can science "work" without philosophy? Some people think that the sciences can stand apart from philosophy, that the scientist should actually avoid philosophising, the latter often being understood as groundless and generally vague theorising. If the term philosophy is given such a poor interpretation, then of course anyone would agree with the warning "Physics, beware of metaphysics!" But no such warning applies to philosophy in the higher sense of the term. The specific sciences cannot and should not break their connections with true philosophy.

Science and philosophy have always learned from each other. Philosophy tirelessly draws from scientific discoveries fresh strength, material for broad generalisations, while to the sciences it imparts the world-view and methodological im pulses of its universal principles. Many general guiding ideas that lie at the foundation of modern science were first enunciated by the perceptive force of philosophical thought. One example is the idea of the atomic structure of things voiced by Democritus. Certain conjectures about natural selection were made in ancient times by the philosopher Lucretius and later by the French thinker Diderot. Hypothetically he anticipated what became a scientific fact two centuries later. We may also recall the Cartesian reflex and the philosopher's proposition on the conservation of motion in the universe. On the general philosophical plane Spinoza gave grounds for the universal principle of determinism. The idea of the existence of molecules as complex particles consisting of atoms was developed in the works of the French philosopher Pierre Gassendi and also Russia's Mikhail Lomonosov. Philosophy nurtured the hypothesis of the cellular structure of animal and vegetable organisms and formulated the idea of the development and universal connection of phenomena and the principle of the material unity of the world. Lenin formulated one of the fundamental ideas of contemporary natural science—the principle of the inexhaustibility of matter—upon which scientists rely as a firm methodological foundation.

The latest theories of the unity of matter, motion, space and time, the unity of the discontinuous and continuous, the principles of the conservation of matter and motion, the ideas of the infinity and inexhaustibility of matter were stated in a general form in philosophy.

Besides influencing the development of the specialised fields of knowledge, philosophy itself has been substantially enriched by progress in the concrete sciences. Every major scientific discovery is at the same time a step forward in the development of the philosophical world-view and methodology. Philosophical statements are based on sets of facts studied by the sciences and also on the system of propositions, principles, concepts and laws discovered through the generalisation of these facts. The achievements of the specialised sciences are summed up in philosophical statements. Euclidian geometry, the mechanics of Galileo and Newton, which have influenced men's minds for centuries, were great achievements of human reason which played 'a significant role in forming world-views and methodology. And what an intellectual revolution was produced by Copernicus' heliocentric system, which changed the whole conception of the structure of the universe, or by Darwin's theory of evolution, which had a profound impact on biological science in general and our whole conception of man's place in nature. Mendeleyev's brilliant system of chemical elements deepened our understanding of the structure of matter. Einstein's theory of relativity changed our notion of the relationship between matter, motion, space and time. Quantum mechanics revealed hitherto unknown world of microparticles of matter. The theory of higher nervous activity evolved by Sechenov and Pavlov deepened our understanding of the material foundations of mental activity, of consciousness. Cybernetics revealed new horizons for an understanding of the phenomena of information interactions, the principles of control in living systems, in technological devices and in society, and also the principles of feedback, the man-machine system, and so on. And what philosophically significant pictures have been presented to us by genetics, which deepened our understanding of the relationship between the biological and the social in man, a relationship that has revealed the subtle mechanisms of heredity.

The creation and development by Marx, Engels and Lenin of the science of the laws of development of human society, which has changed people's view of their place in the natural and social vortex of events, holds a special place in this constellation of achievements of human reason.

If we trace the whole history of natural and social science, we cannot fail to notice that scientists in their specific researches, in constructing hypotheses and theories have constantly applied, sometimes unconsciously, world-views and methodological principles, categories and logical systems evolved by philosophers and absorbed by scientists in the process of their training and self-education. All scientists who think in terms of theory constantly speak of this with a deep feeling of gratitude both in their works and at regional and international conferences and congresses.

So the connection between philosophy and science is mutual and characterised by their ever deepening interaction.

Some people think that science has reached such a level of theoretical thought that it no longer needs philosophy. But any scientist, particularly the theoretician, knows in his heart that his creative activity is closely linked with philosophy and that without serious knowledge of philosophical culture the results of that activity cannot become theoretically effective. All the outstanding theoreticians have themselves been guided by philosophical thought and tried to inspire their pupils with its beneficent influence in order to make them specialists capable of comprehensively and critically analysing all the principles and systems known to science, discovering their internal contradictions and overcoming them by means of new concepts. Real scientists, and by this we usually mean scientists with a powerful theoretical grasp, have never turned their backs on philosophy. Truly scientific thought is philosophical to the core, just as truly philosophical thought is profoundly scientific, rooted in the sum-total of scientific achievements Philosophical training gives the scientist a breadth and penetration, a wider scope in posing and resolving problems. Sometimes these qualities are brilliantly expressed, as in the work of Marx, particularly in his Capital, or in Einstein's wide-ranging natural scientific conceptions.

The common ground of a substantial part of the content of science, its facts and laws has always related it to philosophy, particularly in the field of the theory of knowl edge, and today this common ground links it with the problems of the moral and social aspects of scientific discoveries and technical inventions. This is understandable enough. Today too many gifted minds are oriented on destructive goals. In ancient times, as we have seen, nearly every notable scientist was at the same time a philosopher and every philosopher was to some extent a scientist. The connection between science and philosophy has endured for thousands of years. In present-day conditions it has not only been preserved but is also growing substantially stronger. The scale of the scientific work and the social significance of research have acquired huge proportions. For example, philosophy and physics were at first organically interconnected, particularly in the work of Galileo, Descartes, Kepler, Newton, Lomonosov, Mendeleyev and Einstein, and generally in the work of all scientists with a broad outlook. At one time it was commonly held that philosophy was the science of sciences, their supreme ruler. Today physics is regarded as the queen of sciences. Both views contain a certain measure of truth. Physics with its tradition, the specific objects of study and vast range of exact methods of observation and experiment exerts an exceptionally fruitful influence on all or nearly all spheres of knowledge. Philosophy may be called the "science of sciences" probably in the sense that it is, in effect, the self-awareness of the sciences and the source from which all the sciences draw their world-view and methodological principles, which in the course of centuries have been honed down into concise forms. As a whole, philosophy and the sciences are equal partners assisting creative thought in its explorations to attain generalising truth. Philosophy does not replace the specialised sciences and does not command them, but it does arm them with general principles of theoretical thinking, with a method of cognition and world-view. In this sense scientific philosophy legitimately holds one of the key positions in the system of the sciences.

To artificially isolate the specialised sciences from philosophy amounts to condemning scientists to finding for themselves world-view and methodological guidelines for their researches. Ignorance of philosophical culture is bound to have a negative effect on any general theoretical conclusions from a given set of scientific facts. One cannot achieve any real theoretical comprehension, particularly of the global problems of a specialised science, without a broad grasp of inter-disciplinary and philosophical views. The specialised scientists who ignore philosophical problems sometimes turn out to be in thrall to completely obsolete or makeshift philosophical ideas without even knowing it themselves. The desire to ignore philosophy is particularly characteristic of such a trend in bourgeois thought as positivism, whose advocates have claimed that science has no need of philosophy. Their ill-considered principle is that "science is in itself philosophy". They work on the assumption that scientific knowledge has developed widely enough to provide answers to all philosophical problems without resorting to any actual philosophical system. But the "cunning" of philosophy lies in the fact that any form of contempt for it, any rejection of philosophy is in itself a kind of philosophy. It is as impossible to get rid of philosophy as it is to rid oneself of all convictions. Philosophy is the regulative nucleus of the theoretically-minded individual. Philosophy takes its revenge on those who dissociate themselves from it. This can be seen from the example of a number of scientists who after maintaining the positions of crude empiricism and scorning philosophy have eventually fallen into mysticism. So, calls for freedom from any philosophical assumptions are a sign of intellectual narrowness. The positivists, while denying philosophy in words, actually preach the flawed philosophy of agnosticism and deny the possibility of knowing the laws of existence, particularly those of the development of society. This is also a philosophy, but one that is totally misguided and also socially harmful.

It may appear to some scientists that they are using the logical and methodological means evolved strictly within the framework of their particular speciality. But this is a profound delusion. In reality every scientist, whether he realises it or not, even in simple acts of theoretical thought, makes use of the overall results of the development of mankind's cognitive activity enshrined mainly in the philosophical categories, which we absorb as we are absorbing our own natural that no man can put together any theoretical statement language, and later, the special language of theoretical thought. Oversimplifying the question a little, one may say without such concepts as property, cause, law or accident. But these are, in fact, philosophical categories evolved by the whole history of human thought and particularly in the system of philosophical, logical culture based on the experience of all fields of knowledge and practice.

Knowledge of the course and results of the historical development of cognition, of the philosophical views that have been held at various times of the world's universal objective connections is also essential for theoretical thinking because it gives the scientist a reliable yardstick for assessing the hypotheses and theories that he himself produces. Everything is known through comparison. Philosophy plays a tremendous integrating role in scientific knowledge, particular ly in the present age, when knowledge has formed an extremely ramified system. Suffice it to say, for example, that medicine alone comprises some 300 specialised branches. Medicine has "scalpelled" man into hundreds of little parts, which have become the targets of independent investigation and treatment.

Sciences have become so ramified that no brain, however versatile can master all their branches, or even one chosen field. No one nowadays can say that he knows the whole of medicine or biology or mathematics, as some people could have said in the past. Like Goethe's Faust, scientists realise that they cannot know everything about everything. So they are trying to know as much as possible about as little as possible and becoming like people digging deeper and deeper into a well and seeing less and less of what is going on around them, or like a chorus of the deaf, in which each member sings his own tune without hearing anyone else. Such narrow specialisation may lead, and has in some cases already led, to professional narrow-mindedness. Here we have a paradox. This process is both harmful and historically necessary and justified. Without narrow specialisation we cannot make progress and at the same time such specialisation must be constantly filled out by a broad inter-disciplinary approach, by the integrative power of philosophical reason. Otherwise a situation may arise when the common front of developing science will move ahead more and more rapidly and humanity's total knowledge will increase while the individual, the scientist, for example, will lag farther and farther behind the general flood of information and become more and more limited as the years go by. Aristotle knew nearly everything that was known to his epoch and constituted the substance of ancient science, but today by the time he leaves school the pupil is expected to know far more than Aristotle. And it would be a lifetime's work even for a gifted person with a phenomenal memory to learn the fundamentals of all the sciences.

What is more, narrow specialisation, deprived of any breadth of vision, inevitably leads to a creeping empiricism, to the endless description of particulars.

What are we to do about assembling integral knowledge? Such an assembly can nevertheless be built by the integrative power of philosophy, which is the highest form of generalisation of all human knowledge and life experience, the sum-total of the development of world history. By means of philosophy the human reason synthesises the results of human knowledge of nature, society, man and his self-awareness, which gives people a sense of freedom, an open-ended view of the world, an understanding of what is to be found beyond the limits of his usual occupation and narrow professional interests. If we take not the hacks of science but scientists on the big scale, with a truly creative cast of mind, who honestly, wisely and responsibly consider what their hands and minds are doing, we find that they do ultimately realise that to get their bearings in their own field they must take into consideration the results and methods of other fields of knowledge; such scientists range as widely as possible over the history and theory of cognition, building a scientific picture of the world, and absorb philosophical culture through its historically formed system of categories by consciously mastering all the subtleties of logical thought. Max Born, one of the creators of quantum mechanics, provides us with a vivid example of this process. Born had a profound grasp of physical thought illumined by philosophical understanding of his subject. He was the author of many philosophical works and he himself admitted that the philosophical implications of science had always interested him more than narrow specialised results. After Einstein he was one of the first of the world's leading scientists to realise the futility of positivism's attempts to act as a basis for understanding the external world and science and to deny this role to philosophy.

The philosophical approach enables us to overcome the one-sidedness in research which has a negative effect in modern highly specialised scientific work. For example, natural science today is strongly influenced by integrative trends. It is seeking new generalising theories, such as a unitary field theory, a general theory of elementary particles, a general theory of systems, a general theory of control, information, and so on. Generalisations at such a high level presuppose a high degree of general scientific, natural-humanitarian and also philosophical culture. It is philosophy that safeguards the unity and interconnection of all aspects of knowledge of the vast and diversified world whose substance is matter. As Werner Heisenberg once observed, for our senses the world consists of an infinite variety of things and events, colours and sounds. But in order to understand it we have to introduce some kind of order, and order means to recognise what is equal, it means some sort of unity. From this springs the belief that there is one fundamental principle, and at the same time the difficulty to derive from it the infinite variety of things. The natural point of departure is that there exists a material prime cause of things since the world consists of matter.

The intensive development of modern science, which by its brilliance has tended to eclipse other forms of intellectual activity, the process of its differentiation and integration, gives rise to a vast number of new problems involving world-view and methodology. For example, do any extra terrestrial civilisations exist and is there life in other galaxies? How did the universe arise in its given qualitative determinacy? What is meant by the infinity of space and time? Certain fields of knowledge constantly run into difficulties of a methodological nature. How can one judge the degree to which physical or chemical methods are applicable to the investigation of animate nature without oversimplifying it? In modern science not only has there been an unusually rapid accumulation of new knowledge; the techniques, methods and style of thinking have also substantially changed and continue to change. The very methods of research attract the scientist's growing interest, as discussion at national and international symposiums and congresses shows. Hence the higher demands on philosophy, on theoretical thought in general. The further scientific knowledge in various fields develops, the stronger is the tendency to study the logical system by which we obtain knowledge, the nature of theory and how it is constructed, to analyse the empirical and theoretical levels of cognition, the initial concepts of science and methods of arriving at the truth. In short, the sciences show an increasing desire to know themselves, the mind is becoming more and more reflective.

Not only are the subject-matter of this or that science and the methods of studying it being verified. We are trying to define the exact social and moral role that this or that science plays or may play in the life of society, what it implies or may imply for the future of mankind—benefit or destruction? This trend towards self-knowledge, of which much is said both by scientists and philosophers, is bound to show itself and should show itself in the relationship between philosophy and science.

The methodological significance of the philosophical principles, categories and laws should not be oversimplified. It is wrong to suggest that not a single specific problem can be solved without them. When we think of the place and role of philosophy in the system of scientific cognition, we have in mind not separate experiments or calculations but the development of science as a whole, the making and substantiation of hypotheses, the battle of opinions, the creation of theory, the solving of inner contradictions in a given theory, the examination in depth of the initial concepts of science, the comprehension of new, pivotal facts and assessment of the conclusions drawn from them, the methods of scientific research, and so on.

Karl Jaspers, the German psychiatrist and philosopher, once made the point that students who became dissatisfied with philosophy often entered the natural scientific faculties to get to grips with "real things", which they then studied enthusiastically. But later, when they began to seek a basis for their own lives in science, the general ruling principles of their actions, they were again disappointed and their search led them back to philosophy. Philosophy, besides all its other functions, goes deep into the personal side of human life. The destiny of the individual, his inner emotions and desires, in a word, his life and death, have from time immemorial constituted one of the cardinal philosophical problems. The indifference to this "human" set of problems, which is a characteristic feature of neopositivism, is rightly regarded as one-sided scientism, the essence of which is primitively simple: philosophy must be a science like natural science, and strive to reach the same ideal of mathematical precision and authenticity. But while many scientific researchers look only outwards, philosophers look both outwards and inwards, that is to say, at the world around man and man's place in that world. Philosophical consciousness is reflective in its very essence. The degree of precision and the very character of precision and authenticity in science and philosophy must therefore differ. Who, for instance, reflects man's inner world with all its pathological aberrations "more precisely"—the natural scientist with his experimental techniques, mathematical formulae and graphs or, for example, Shakespeare, Tolstoy, Dostoyevsky, in their immortal works that are so highly charged with philosophical meaning?

At this point a huge philosophical problem arises. How are we to overcome the yawning gap between mathematised natural-scientific and technological thinking, on the one hand, and humanitarian, social thought, on the other? How are we to resolve the intense and continuing argument between the so-called "lyricists and physicists", who symbolise these two diverging styles of thought? This is something that has a harmful effect on the human personality, dragged in opposite directions by the two principles. This morbid dichotomy may have negative consequences for the present and future of both the individual and collective human reason. So it is an educational, philosophical, moral and profoundly social problem.

Philosophy, as we have said, is not simply an abstract science. It also possesses an evaluative aspect, its moral principles. Science has given man a lot of things, but ethics or, to put it more bluntly, conscience, is not one of them. The evaluative, axiological and aesthetic aspects are also important for science. And they are not part of it either.

Philosophy helps us to achieve a deeper understanding of the social significance and general prospects of scientific discoveries and their technical applications. The impressive achievements of the scientific and technological revolution, the contradictions and social consequences it has evoked, raise profound philosophical problems. Contemporary philosophical irrationalism gives a pessimistic appraisal of scientific and technological advance and predicts worldwide disaster. But this raises the question of the responsibility of philosophy, since philosophy seeks to understand the essence of things and here we are dealing with the activity of human reason and its "unreasonable" consequences. Thus the question of the nature of philosophy in our day grows into a question of the historic destinies of humanity and becomes a vitally important social problem. To what extent can society comprehend itself, rationally control its own development, be the master of its own destiny, command the consequences of its own cognitive and practical activity?

There are many questions that the epoch poses before humanity and these questions can be answered by philosophy. For example, what does the future hold for the contesting social systems in the modern world? What are the rational ways of removing the threat of universal annihilation?

In present-day conditions the role not only of natural science and technology, but also of the humane sciences that study "human affairs", the laws of life and development of society, has grown enormously and will continue to do so as time goes on. The results of social research have today assumed not only exceptional theoretical but also exceptional applied, social and political importance. The very structure of social life is becoming more complex, new forms of human activity are appearing, the scientific and technological revolution continues its advance, the role of social and political problems in the life of society, in the development of culture is steadily increasing.

Revolutionary changes have today invaded all spheres of life: the productive forces, science with its gigantic field of practical application, technology, politics, ethnic relationships, intellectual life in general. Man himself is changing. What is the essence, the cause of these changes that are spreading across the world and affecting the most diverse aspects of human life? In what way do the various aspects of the revolutionary process that has gripped the planet interdepend? What consequences will the scientific and technological revolution have for the nations of the world? Are we not witnessing and participating in a profound crisis of our whole civilisation? What are we to do about elevated human ideals when we are confronted with a threat to the very existence of life on earth?

For several centuries people hopefully observed the development of technology on the assumption that taming the forces of nature would bring them happiness and plenty, and that this would be enough to allow human life to be arranged on rational principles. Mankind has achieved a great deal, but we have also made "a great deal of mess". For how long and on what scale can we go on accumulating the waste products among which modern man has to live? Here we need a clear and philosophical view of history. Why, because of what contradictions, do the forces created and activated by human brains and hands turn against man himself and his mind? Why is the world so constructed that more of its gifted minds are bent on destruction instead of creation? Is this not a profound social and philosophical problem? The advent of the atomic age was marked by horrifying annihilation and mass murder. For how long will the menacing shadow of the atomic bomb hang over all human joys and hopes?

These and other great questions of our time cannot be answered by the supreme science of physics, by mathematics, cybernetics, chemistry, biology, or by natural science as a whole, great though their discoveries have been. These questions, which exercise the minds of all mankind and relate to life today and in the future, must be answered by scientific philosophy.

Naturally, the solution of all the pressing problems of our time depends not only on a rational philosophical orientation. It also depends on the political orientation of nations and statesmen, which in turn is related to the nature of the social structure.

Scientific activity is not only logical, it also has moral and socio-political implications. Knowledge arms man with the means to achieve his ends. There can be no doubt that modern natural science is a powerful "motor" of technical advance.

In a fierce ideological struggle the specialised scientists who lack any scientific world-view or methodology sometimes turn out to be helpless grown-up children in the face of reactionary ideology and some of them fall into its clutches.

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