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The Nature and Origin of Scientific Method [1948]

THIS PAPER WAS published in *The Listener*, 39 (27 May 1948): 865–6, under the title "Science as a Product of Western Europe"; it was reprinted, with the present title, in *The Western Tradition: A Series of Talks Given in the BBC European Programme*, (Vox Mundi Books, November 1949): 23–28. In 1951 The Beacon Press of Boston published this book with the title, *The Western Tradition: A Symposium*. Although the date of its broadcast on the BBC is not known, it was probably shortly before its publication in *The Listener*. On 14 July 1948, Terrence Cooper of the BBC wrote to Russell:

> Thank you for your letter giving permission for your talk "The Nature and Origin of Scientific Method" to be published in the Latin-American Press. The Corporation has the right to publish talks in its own journals—*The Listener*, *Radio Times*, etc.—within a month of the date of broadcast. With this exception, all publication rights remain with you.

From this letter it seems likely that Russell's own title for the essay is the one selected for this edition.

The copy-text is the version in *The Listener*; it has been collated with the Vox Mundi version, and the results are reported in the Textual Notes.

SCIENCE, LIKE MOST things, was gradual in its beginnings, and it was not until the seventeenth century that it began to acquire a decisive position. It has since grown to be the most distinctive characteristic of our age; for good or evil, it is what makes our age different from antiquity and the medieval centuries.

Science may be defined as the discovery of causal laws by means of observation and experiment—laws which are more valued when they are quantitative than when they are merely qualitative. Mathematics, which does not require observation, owes its first considerable development to the Greeks, but the only observational study in which the Greeks were proficient was astronomy, where there are very obvious uniformities and much can be done by pure geometry. It was not until Galileo that a way was found of dealing with motions that are not uniform and not periodic. Before his time men sought laws of stability; but in modern times laws of change have been what science has mainly wished to find. And ever since Bacon science has been valued, not only, or even chiefly, as pure knowledge, but as a source of power—power over inanimate nature, power over plants and animals, and now, at last, power over human communities.

Science is a product of Europe. The only exception of importance that I can think of is the Babylonian discovery that eclipses could be predicted. A very few nations—Italy, France, the Low Countries, Britain, and Germany—contributed quite ninety per cent of the great discoverers. Poland contributed Copernicus, Russia contributed Mendeleeff and Pavlov, but on the whole the share of Eastern Europe has not been a large one. Within Western Europe, as may be seen from a map showing the birth-places of eminent men of science, there has been a correlation with commerce and industry. But commerce does not necessarily lead to science. It did not do so among the Phoenicians and Carthaginians, and the Arabs, though they studied science of a sort, made no discoveries in any way comparable to those of Western Europe since 1600. I do not think that seventeenth-century science can be regarded as an inevitable outcome of social and economic conditions; the existence of individuals possessed of very rare abilities was also necessary. Why they should have been born there and then cannot be explained in scientific terms by means of our present knowledge. It certainly does not have a racial explanation, as may be seen from the fact that many of the best men of science have been Jews, who though living in Western Europe are not of course of West European stock.

The importance of the economic conditions which attended the beginnings of modern science has been so much emphasized that the intellectual conditions have tended to be overlooked. Let us spend a few moments in considering scientific method in itself, apart from the social environment that promoted it.

The essential matter is an intimate association of hypothesis and observation. The Greeks were fruitful in hypotheses, but deficient in observation. Aristotle, for example, thought that women have fewer teeth than men, which he could not have thought if he had had a proper respect for observation. Francis Bacon, on the other hand, overestimated the mere collecting of facts, supposing that this, if carried far enough, would of itself give rise to fruitful hypotheses. But there are so many facts, and so many ways of arranging facts, that no one can collect facts usefully except under the stimulus of some hypothesis to which they are relevant. Throughout any scientific investigation, even from the very beginning, generalizing hypotheses must exist in the mind of the investigator to determine the direction of his observations. The hypotheses must, however, continually change and develop as new facts prove the old hypotheses to be inadequate. It is commonly said that the framing of hypotheses is the most difficult step in scientific investigation, and perhaps this is true of men who have undergone a thorough education in science. But viewed historically it would seem that respect for fact is more difficult for the human mind than the invention of remarkable theories. It is still believed by a large percentage of the inhabitants of this country that people born in May are specially liable to corns, that the moon affects the weather, and that it is dangerous to see the new moon through glass. None of those who hold these theories think it necessary to verify them. Aristotle's physics, as interpreted by medieval commentators, supplied a number of admirable theories, which covered the ground much more adequately than Galileo could do. There was nothing against the theories except that they were not in accordance with the facts, but this objection struck Galileo's Aristotelian adversaries as frivolous. And when he discovered Jupiter's moons their existence was denied, on the ground that the number of the heavenly bodies must be seven. I think, therefore, that in the beginning the respect for fact demanded by science is more difficult even than the framing of what may prove good hypotheses. And the hypotheses that prove good are very seldom such as commend themselves to our initial prejudices.

As against Bacon, the history of science seems to show that even the worst hypothesis is better than none. The beginnings of chemistry were dominated by the search for the philosopher's stone and for means of turning base metals into gold. This search supplied an essential element in scientific method which was absent in astronomy—I mean *experiment* as opposed to passive observation. If the medieval alchemists had not had extravagant hopes, they would not have had the patience to accumulate gradually a great mass of fact which could only become known by the artificial creation of conditions not spontaneously produced by nature. This work, which the Arabs took over from Alexandria and the Christians from the Arabs, supplied much detailed knowledge, but did not yield anything scientifically systematic until the time of Lavoisier and Priestley at the end of the eighteenth century. And it was not until our own day that the diversity of chemical elements was fitted into an unitary theory, and that the transmutation of elements became a practical possibility—with consequences that, if not controlled, threaten disaster to mankind.

The prejudices against scientific investigation of facts has been strongest where human beings are concerned. Throughout the middle ages anatomy was hampered by a rooted objection to dissection of corpses. Vesalius, who was Court physician to Charles V and Philip II, ventured, under the protection of royal favour, to defy this prejudice. But his enemies accused him of having dissected a body while still alive, and he was sentenced, as a penance, to a pilgrimage to the Holy Land. During his return he was shipwrecked and died of exposure. In China, not many years ago, a French surgeon, who had been invited to found a medical school, demanded corpses for dissection. He was told that to cut up corpses would be an impiety, but that he could operate instead upon living criminals. These two opposite stories both illustrate the obstacles to a scientific outlook.

Western Europeans, and men in the New World whose ancestors, whatever their racial origin, had lived in Western Europe, had for about three centuries a virtual monopoly of science, and acquired thereby a supremacy throughout the world such as neither they nor anyone else had possessed at any earlier time. This monopoly, of course, could not last for ever. Although the Japanese challenge proved unsuccessful, European dominion in Asia is disappearing, and we may expect a growth of Asiatic science as a result of political independence. Now that scientific method has been developed, a great deal can be achieved without the genius that was necessary in the pioneers. Any man possessed of patience and fair abilities and the necessary equipment can, nowadays, be pretty sure to find out *something*, and it may happen to be something of great importance. I do not think that Mendel's work required any very extraordinary gifts, and yet the Mendelien theory of heredity is transforming scientific agriculture and stock-breeding, and probably will in time considerably alter the congenital character of human beings. The more science advances, the easier it becomes to make new discoveries; that is why the rapidity of scientific progress has been continually increasing since the seventeenth century.

Science has been victorious over the prejudices that opposed its progress, because it has conferred power, and especially power in war. Archimedes, almost the only *experimental* scientist among the Greeks, was useful in the defence of Syracuse. Leonardo da Vinci was employed by the Duke of Milan because he understood the science of fortification. Galileo, similarly, was supported by the Grand Duke of Tuscany because his researches on projectiles showed how to make artillery more effective. In the French Revolution French men of science played a vital part in the defence of their country against its many enemies. In the recent war it was scientific superiority that secured the final defeat of Japan. For such reasons, there is now little active opposition to scientific technique and scientific methods of investigation.

But power without wisdom is dangerous, and what our age needs is wisdom even more than knowledge. Given wisdom, the power conferred by science can bring a new degree of well-being to all mankind; without wisdom, it can bring only destruction.

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141: 12–13 **It was not until Galileo ... and not periodic** Galileo Galilei (1564–1642) was the first to apply mathematics to the mechanics of accelerating objects, especially gravitational acceleration.

141: 15–17 **since Bacon science has been valued ... as a source of power** Bacon asserts this parenthetically in the section on heresies in *Meditationes Sacræ* (1597) See Bacon *1861*, VII: 253. For the Latin original "Nam et ipsa scientia potestas est" see *ibid.*, 241.

141: 20 **the Babylonian discovery that eclipses could be predicted** The Babylonians discovered what is known as the "Saronic cycle", "the interval of eighteen years and eleven and one-third days, a multiple of which Babylonian temple star-gazers had shown to be usual between eclipses of the sun" (Singer *1959*, 15).

141: 23 **Mendeleeff** Dmitri Ivanovich Mendeleeff (1834–1907), a Russian chemist, established the periodic table and predicted that the missing elements would have certain properties; his predictions were verified by the discovery of gallium in 1875, of scandium in 1879, and of germanium in 1886.

141: 23 **Pavlov** Ivan Petrovitch Pavlov (1849–1936) made important discoveries about conditioned reflexes in dogs.

142: 3–4 **Aristotle ... thought that women have fewer teeth than men** See Aristotle's *History of Animals*, Bk. II, 501b: 20–1, where he states that "males have more teeth than females in the case of men, sheep, goats, and swine".

142: 5–7 **Francis Bacon ... fruitful hypotheses** See his *Novum Organum* for an exposition of the method Russell is criticizing here.

142: 27–9 **he discovered Jupiter's moons ... must be seven** Galileo's discovery that Jupiter had moons upset his contemporaries in two ways: some were shocked because it contradicted the received opinion that all celestial bodies revolved around the earth; others because it contradicted another received opinion that there were only seven heavenly bodies—the sun, the moon, and the five known planets—besides the fixed stars. As Andrew Dickson White, one of Russell's favourite authorities, notes, the reasoning in support of seven bodies was curious: "this was proved by the seven golden candlesticks of the Apocalypse, by the seven-branched candlestick of the tabernacle, and by the seven churches of Asia" (*1896*, I: 131). See also Russell *1935*, 35–41 for a discussion of this point.

142: 35 **the philosopher's stone** Alchemists sought this alleged substance because it was believed to have the power of transforming base metals into gold or silver; it was supposed also to be the source of the "elixir of life", a fluid which could be distilled from it that, when drunk, would revitalize physical and spiritual health as well as prolong life. In their searches alchemists tested many natural substances and tried combining them in various ways; the records of their research formed the bases of experimental chemistry, metallurgy and pharmacology.

143: 1 **the time of Lavoisier** The French scientist, Antoine-Laurent Lavoisier (1743–1794), is generally considered to be the founder of modern chemistry; he is best known for his role in the discovery of oxygen.

143: 1 **and Priestley** Joseph Priestley (1733–1804) was an English clergyman, political theorist, and scientist, who contributed greatly to each of these fields; he was one of the discoverers of oxygen.

143: 8–13 **Vesalius ... died of exposure** Andreas Vesalius (1514–1564) was a Renaissance physician whose detailed observations, based upon human dissections, greatly advanced the study of anatomy and the practice of medicine. See White (II: 51–4) for an account of his persecutions.

143: 9 **Charles V** Russell is referring to Charles V (1500–1558), Holy Roman emperor and King of Spain, who reigned from 1519 to 1556, and in whose court Vesalius worked for a time. Vesalius dedicated his great work to Charles V.

143: 9 **Philip II** Philip II of Spain (1527–1598) was a son of Charles V and reigned from 1556 until his death. Vesalius joined his court as a physician in 1559, and it was there that he was falsely charged with dissecting a living man. Philip II, whom Andrew Dickson White calls "a scribbling bigot" (*1896*, I: 176), neglected to protect him from his persecutors and he became a wanderer.

143: 31–2 **Mendel's work ... theory of heredity** Gregor Johann Mendel (1822–1884) was an Austrian monk and teacher who conducted experiments on plants and their heredity; his discoveries provided important data for the mathematical study of genetics.

143: 39–41 **Archimedes ... was useful in the defence of Syracuse** Archimedes (*c.*287–212 B.C.) was a Greek mathematician, scientist and inventor who was one of the first to state general mathematical laws which were based upon observation and experiment; he also invented many military devices, some of which were employed in the defence of Syracuse against a Roman invasion; he was killed by a soldier during the Roman capture of Syracuse.

143: 41–2 **Leonardo da Vinci ... science of fortification** In 1483 Leonardo da Vinci (1452–1519), the brilliant Florentine artist, scientist and thinker, began working for Ludovico Sforza (1451–1508), who became the Duke of Milan in 1481. In his letter of application he enumerated several of his innovations in the art of war. These included "very light bridges … which will resist both fire and sword"; "secure and covered wagons for the transport of guns into the enemy's lines"; and "ships which are both gun-proof and fire-proof" (Hart *1925*, 44–5).

143: 42–144: 1 **Galileo ... showed how to make artillery more effective** In 1592 Galileo took a chair of mathematics at the University of Padua. During his stay he offered a private course on military architecture and invented an elevation gauge for gunners. For the details of this and his other inventions relating to artillery see Drake *1978*, 38–40. Cosimo II, the Grand Duke of Tuscany to whom Russell refers, was originally Galileo's pupil. In the summer of 1610 Galileo left his position as professor at Padua to take an appointment as "first philosopher and mathematician" to his court.

144: 3–4 **In the recent war … defeat of Japan** Russell is of course referring to the use of atomic bombs by American forces against Japan at the close of the Second World War.

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The textual notes provide a collation of the copy-text as published in *The Listener* ("CT") with the version in *The Western Tradition* ("49").

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