

An Introduction to
Early Modern Europe
1400-1789

A Political Social Economic and Cultural History

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4.2 Copernican Revolution

Nicholas Copernicus (1473-1543) was the pioneer in the scientific revolution of the sixteenth century. A Pole by birth, he received his education in the universities of Italy and by profession he was a churchman. He studied law, medicine and astronomy, the last one was his first love. The medieval scholars started asking various questions about the existence of man and his position in the universe. People wanted to know about the creation. Arithmetic of Pythagoras, geometry of Euclid, science of Plato, engineering laws of Archimedes, Ptolemy's astronomy and the medical science of Galen constituted the scientific world of this time. Aristotle, Galen and Ptolemy got mixed up with theological speculations and the entire process came to be known as scholasticism. The Roman Catholic Church and the

state supported this scientific investigation. Science had no conflict with the state and the church. In the middle ages it was taken for granted that the scientific investigation was only for the sake of knowledge, it has no practical use. Scientific laws were known only to the students, book learning and disputation asked questions about the universe that helped expand the frontier of knowledge.

Scientific revolution of the sixteenth century marked a radical departure from this traditional thinking about science. The Renaissance taught man to think rationally and to ask questions. The light of reason breached the walls of conservative thinking. Its socio-economic context was the break-down of feudalism and a sharp change in the system of production. The feudal system of production was replaced by a capitalist system whose main features were production and monetisation. The salient features of scientific revolution were observation, experimentation and mathematical explanation. There is no doubt that the economic transformation prepared the ground for scientific revolution. The development in agriculture, industry and trade necessitated the application of science and technology. 'It was the demands of economic progress that brought about the growth of scientific enquiry'. It was not that scientific progress made economic development possible. It was otherway round. In the sixteenth century wars and colonial activities went side by side. Navigation, trade, ship building and the manufacture of armaments facilitated the growth of science and technology. The Europeans had built up colonies in America, while sea-routes to the east were discovered. Colonial trade increased the wealth of European nations. For long distance navigation the Europeans needed better ships, compass and astrolabs. Portugal, Spain, England, Holland and France set up institutes for the training of navigators. Intimately related to this was astronomy as the navigators needed knowledge of the earth, planets, stars and their orbits. People wanted to know more about them.

In the Aristotelian cosmology our earth stood at the middle, giving glory and prestige to man. In this cosmos everyone

starting from God, man, angel, botanical and zoological species had their definite unchangeable position. He gave out a theory of origin of the universe which the European people readily accepted. It was taken for granted that the universe was created as the God willed it, and it has remained unchanged for centuries. But this theory of creation was challenged by Cicero and Hicetus who said that the earth was revolving in its orbit. Greek philosopher Aristarcus first speculated that the earth is revolving round the sun. The idea of solar-centric universe is not new, it was not the invention of the Renaissance scientists. It was not accepted because the scientists failed to prove their theory with sufficient evidence. But as an alternative theory it remained to agitate the mind of the thinkers. Common people did not accept the idea as it was visible that the sun, moon and the stars were moving around. To change this accepted view of the universe two things—science and courage—were needed. This was exactly the work that Copernicus did. He had courage and got inspiration from the renaissance humanists.

Copernicus devoted his life to the service of astronomy which was his favourite subject. At the end of his life he wrote his magnum opus '*On the Revolution of the Celestial orbs*'. In this work Copernicus explained that planets and stars were revolving not round the earth but the sun. The earth also is revolving round it who is standing like a king in the universe. The Copernican theory was not accepted in his life time, it was recognised by the scientists hundred and fifty years after his death. Giordino Bruno preached his theory for which he was convicted and punished with death. The Danish astronomer Tycho Brahe advanced this theory a little further. Kepler suggested that the orbits were half-circle and oval shaped. Galileo established this theory of the universe with the help of velocity and theory of motion. The Copernican theory got the recognition of the scientists.

4.3 Revolution in Science and Technology

Generally it is assumed that the scientific revolution is nothing but new inventions in science and technology. In the sixteenth

and seventeenth centuries there was no invention in science and technology. If there was a revolution it was in the sphere of scientific thinking. Ideas about the universe radically changed. There was a new concept about the relation between the universe and our planet the earth. There was growing curiosity about the position of man in the cosmos. Scientific revolution meant a revolution in the attitude, concepts and the entire philosophy of science. Scientific investigative mind was steadily coming into being. The investigative people were seeking new definition of the physical world, all physical phenomena came under intensive investigation. Scientists wanted to know the reasons for planetary movements, causes of floods, cycle of seasons etc. The movement of the earth and the specific position of the earth in this cosmos became the subjects of observation and investigation.

Three problems were associated with the scientific investigation. If every thing was natural, God has nothing to do with it then what would be the position of man in the universe. If every phenomenon can be explained by cause and effect, what would be its overall impact, what would be the universal language of science. In the medieval period every thing was explained as the manifestation of the will of God. Aristotle and his logic provided the universal language of science. But it was new Europe with new men and mentality. Humanist learning changed the outlook of man, the Aristotelian logic could not explain all things on earth. So it was replaced by a science with emphasis on observation and experimentation. The new universal language of science was mathematics. Science was disciplined knowledge, the whole concept of science underwent a change. Nicholas Copernicus rejected the old theory of the universe and created a new one based on the sun. In every twenty four hours the earth was revolving round the sun. He wrote 'On the Revolution of the celestial orbs' to explain his new theory. Giordino Bruno preached this theory and was punished with death as it was supposed to be a sacrilege. The greatest astronomer of the age of science was Tycho Brahe of

Denmark who created the first astronomical research laboratory. Johan Kepler advanced the theory of evolution further.

Galileo Galilei was one of the greatest scientists of this age. He was a physicist and an engineer, the inventor of telescope. He was the professor of Padua University in Italy where he laid the foundations of two new branches of science—statics and dynamics. He wrote two important books on science—Dialogues on two new sciences and Dialogue concerning the two chief systems of the world. He was in constant search for a new scientific method. Galileo and Kepler were both brilliant mathematicians. Vieta founded the science of Algebra and Trigonometry. Symon Stevin who invented the decimal system laid the foundation of Hydrostatics and Hydraulics. Leonardo and Galileo were the pioneers of scientific engineering. William Gilbert was the first to talk of magnetic field, Hartman and Robert Norman were profoundly influenced by him.

Not only in the field of science, progress was also made in the sphere of technology. Extraction from mines, metallurgy and chemistry made much progress. People no longer trusted alchemy and magic. But superstition still dominated society as Shakespeare and Marlowe always brought ghosts and demons in their creation. People consulted magicians and astrologers. The progress of science could not make them retreat. The conservative intellectuals like Cornelius Agrippa opposed the development of new science. The church did not recognise it. With chemistry medical science also advanced. Hohenheim Paracelsus was the medical scientist of the Renaissance period who criticised the theories propounded by Galen and Abesina. Science advanced because the scientists of the age found solutions to the every day problems of the people. Agricola of Germany laid the foundation of geology as he was in search for solutions to the problems of the miners. Van Helmont and Andreus Vesalius were the pioneers in the study of physiology. The British scientist William Harvey first invented that blood is circulating in the whole body. It was as great an invention as the theory of Heliocentric world. New Science was popularised

by Francis Bacon (1561-1626) who concentrated on the development of scientific method. In his *Novum Organum* he emphasized the need to observe and experiment. He was one of the proposers of the Royal Society which eventually came into being in the 1660s. In France Louis XIV founded the Royal Academy of Sciences, societies and academies were numerous, Portugal had a centre for oceanic research, Denmark an astronomical laboratory. Rene Descartes in his *Discourse* on method anticipated the vast possibilities of science. He is one of the founders of scientific method of enquiry.

Scientific community comprised all sorts of people—professors, intellectuals, clergymen, mechanics, metallurgists, engineers, chemists and physicians, Robert Boyle researched on steam engine, Rupert Hooke on elasticity. His invention is known as Hooke's law. John Dee enquired into the geographical problems. The greatest scientist of the seventeenth century was Isaac Newton (1642-1727) whose *Principia Mathematica* (1687) marked the apogee of the scientific revolution. In this work he expounded the theory of gravitation which laid the foundation of scientific method. Mathematics is the key to the understanding of the physical world. Newton was a rationalist and his rationalism not only influenced the scientists but also the social scientists of the time who extended it to the ideas of natural rights of man. The basic principle of new science was to go to the roots of the problem, only rationalism would not help. New science freed man from superstition, science freed itself from parochialism. Galileo and Descartes thought of practical application of science. It was no longer an abstract idea, society can immensely benefit from it. Observation, experimentation and mathematical precision took science to a new height which was helpful in modernisation.

J. D. Bernal is of the view that the new science was the contribution of the bourgeoisie. The economic development of Europe increased the demand for commodities which again created a new demand for technology. Extraction from mine, war and navigation brought new problems to the fore.

Geographical discoveries and new colonies increased the demand for science and technology. By the end of the seventeenth century a group of scientists were able to solve the problems of power and astronomy. To find solutions to scientific problems they applied experimental and mathematical laws. Science was coming to help man and society. In the sixteenth and seventeenth centuries change in science and scientific attitude was far more important than changes in political and religious life. According to Bernal the very change in scientific thinking was at the heart of scientific revolution. The Greek, Islamic and Christian clergymen had built up an artificial edifice of science which was coming down under the impact of new science. What these two centuries brought to the fore was a new thinking and a new method. The medieval cosmology was based on theology, not scientific. New science gave out a new explanation based on scientific observation and experiment. Aristotle was replaced by Newton who gave a new theory of the universe. The new science was at once destructive and constructive, the old was destroyed and a new scientific theory of the universe was built on its ruins. Old ideas, place of man and God in the universe all received the impact of new science.

Scientific revolution meant a new thinking in science. It was earlier assumed that the universe was changeless and unchangeable. The relation of man with the universe was not to be changed. New science accepted the natural laws and wanted to control it. A new curiosity grew out of the material world which created a new outlook. Scientists started to look into the machines and tools of the artisans. New scientists were men of the upper layers of society, while the artisans were men of the lower orders. A sort of rapprochement was effected between them as the former were coming to the help of the latter. The new scientists like Copernicus, Harvey and Newton never disowned the past, they built up their new system on the tradition of the old. Following the old system at the outset they brought about a new scientific revolution.

The starting point of this scientific revolution was the Renaissance which continued right up to the end of the seventeenth century. The revolution was disrupted by the religious wars. At the beginning of the revolution the scientists rejected first the idea of earth-centric universe and preached the idea of solar centric cosmos. Reinhold, John Field, Robert Record, and Thomas Diggs all preached the Copernican theory. Copernicus pointed out the fallacies of Ptolemaic theory. Johan Kepler and Galileo also took forward the Copernican idea of the universe. As it was going against the genesis theory of the Bible Galileo had to spend his last years in the prison of the church. Galileo invented a few new laws of science which included such things as motion, velocity and power which laid the foundation for modern science.

Andreas Vesalius wrote *De Fabrica* and brought about a revolution in medical science. William Harvey expounded the theory of blood circulation. Science was making steady progress over the years in such fields as steam, velocity, motion and mathematics. Newton laid on firm foundation the principles of modern science which could sufficiently explain creation and the universe without any reference to God. Man can control everything if these basic principles of science are followed scrupulously. Science is not only for the sake of science, it is also for the well-being of man.

4.4 Science Academies

The study of science was institutionalised in science academies. From the Renaissance onwards it was felt that the universities where science was taught were not suitable centres for the study and experiments in science. With the printing revolution and the spread of scientific culture the people at higher levels of society felt the need for science societies where the scientists can meet and exchange their ideas. Social demands are the mother of scientific inventions. The society needed new technology and instruments especially in pumping, hydraulics, navigation, mechanics and astronomy. In this age of scientific discoveries

not only very learned scholars but also mechanics and artisans were associated with experimental science for which they were made members of scholarly science bodies. The academies were formed in different countries of Europe, especially in the seventeenth century, mainly for discussion and experiments. The scientific mentality and its practical utility thus spread among the common people of Europe.

The Protestant movement in Europe gave fillip to the study of science as the Puritans demanded reorientation of the courses of study. Aristotelian scientific world was no longer sufficient for the new generation of scholars. Geometry, Physics, Chemistry and Life Science were the new areas of study in the new universities of Europe. Even old universities like Oxford and Cambridge emphasised the study of basic sciences and life science. There is no doubt that from the forties of the seventeenth century several study clubs came into being in Oxford, Cambridge and London. Oxford Experimental Philosophy Club was one such institution. The discussion that took place in these clubs were propagated among the people. John Wilkins, Warden of Wadham College, was the moving spirit behind such group discussions and weekly meetings. But early modern Europe made a beginning in scientific discussion in the Plato Academy of Florence. Before that Rome had Academia Dei Lincei and Florence had Cimento. These were probably the first science bodies of Europe but unfortunately these academies did not survive for a long time for want of patronage and financial support.

Several science academies came to be formally established in the seventeenth century. The ground for such bodies was prepared by such illustrious men as Amos Comenius, John Ray, and mathematician Wallich, Robert Boyle, Sir William Petty and Christopher Rein. Before Royal Academy formally came into being in 1662 the scientists met at Gresham college to discuss scientific issues and exchange ideas. It was the meeting place for the budding scientists of England. A group also met at oxford weekly to discuss scientific problems and experimental

methods. These efforts blossomed forth into Royal Academy established by a Royal charter in the reign of Charles II. But it is to be noted that though the Royal Academy was founded by the king it was not financially supported by him. It had to depend on the subscriptions of the members and patronage of the rich. The Royal Society published its journal Philosophical Transactions from 1665 onwards. Thomas Spratt has given the details of this institution in his History of Royal Society.

The French came forward to establish such a science academy in the reign of Louis XIV. The French scientists used to meet at Aix-en-Provence since 1620 in the house of a rich lawyer. The famous scientist Gassendi used to attend these meetings. The prime minister of Louis XIV Colbert was eager to expand French economy, especially its trade and industry. He was one of the inspirations behind the formation of French Academic Royale des Sciences in 1666. Among others who promoted science culture in France were Mersenne Renaudot and Montmor. They invited scientists to meet in their houses and discuss their problems. But it should be noted that atmosphere for the growth of scientific enquiries was not so congenial in France as it was in England. Cardinal Mazarin extended support to these pioneers of science studies in France. Western Europe had several such science academies. The famous German mathematician and philosopher Leibnitz brought about such an institution in Germany which prepared the meeting ground for the scientists of Germany. They emphasised the study of physical science, life science and mysteries of nature and excluded discussions on philosophy, religion and metaphysics. This was the general trend all over Europe. Bologna in Italy was famous for the study of science, it had a science academy which was the meeting place for the scientists, medical men, chemists and astronomers. There is no doubt that science academies played a great part in the rise and spread of scientific spirit. Taicho Brahe in Denmark founded the first astronomical laboratory in that country. Astronomy was an important field of enquiry for the scientists. J. D. Bernal has often stated that

scientific inventions were the result of social demands. The society demanded new instruments, new technology as well as fundamental researches in science for the development of human society. The new outlook, scientific mentality and quest for the unknown were the real spirit behind the creation of science academies.