UNIT 7 THE MODERN SCIENCE*

Structure

7.0 OBJECTIVES

After reading this Unit, you will understand the following aspects about development of science in seventeenth and eighteenth centuries:

- nature of modern science especially its experimental nature,
- major development in various fields of science,
- different interpretations of scientific development by historians; and
- the role of women in development of science.

7.1 INTRODUCTION

Science is often defined as the systematic study of the natural phenomenon. Its basic human tools are observation and experiment. *Science* is the concerted human effort to understand, or to understand better, the history of the natural world and how the natural world works, with observable physical evidence as the basis of that understanding. Defined in this manner, scientific progress, the driving force for the rise of modernity, requires a critical mind, free of prejudice and opens to new ways of thinking. Presently, science is used in a narrow technocratic social world. This has led to an understanding that whatever is technically feasible and achievable, we should attain that, regardless of human and environmental cost. However, modern science itself emerged as a neutral and value-free discipline in seventeenth and eighteenth centuries in a slow and long process. It was only a couple of centuries later that it was subjected to the control of the ruling oligarchies who misused scientific knowledge to destroy mother earth's environment or to create weapons of mass-destruction which can wipe out the entire human civilization. Sometimes in the initial phase of development, modern science was

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a dangerous business as it came into conflict with the established authority of Church in Europe. In 1600, the Italian monk Giordano Bruno was sentenced to death and burned at the stake because he believed in free thinking in philosophy and science. Famous Scientist Galileo Galilei narrowly avoided the same fate but only by publicly renouncing his support of Copernicus' heliocentric view (the view that planets including earth revolves round the sun.) In this Unit, we will discuss the story of main developments of modern science in Europe in seventeenth and eighteenth centuries, the interpretations of these developments, the causes for its development, the context of its development and its impact on society and culture.

7.2 NATURE OF MODERN SCIENCE AND KNOWLEDGE SYSTEM

Modern science tries to understand and explain how nature works and why things look to us as they exist. "Natural" here refers to empirical or "sensible," that is, only that which we can detect — somehow — with our senses or with tools that are extension of our senses. It involves explanations that are meticulous, accurate and possess predictive power. In addition to being limited to studying the natural world, scientific knowledge is limited by being inherently uncertain to varying degrees. It does not claim absolute, eternal, fixed, infallible or permanent truth. It is based on a realistic perception of the physical universe as existing apart from our sensory perception of it. It is also assumed that humans have potential to accurately perceive and understand the world and its working. Empirically-accessible processes are enough to explain or account for natural phenomena or events. Scientists also assume that nature function uniformly in both space and time (unless we have evidence to the contrary). Since our scientific knowledge is based only on human sensory experience of the natural world, it is subject to the limitations. For example, we cannot see either infrared or ultraviolet light and we cannot hear extremely high or low sounds. But there may be tools which may enhance power of our observations through senses, there are still limits to accuracy and range of instruments made by humans. Sometimes our previously held notions of the world or some phenomenon in the world continue to influence our perception as the saying goes that we see with our minds, and not with our eyes. Scientific knowledge is, therefore, necessarily contingent or dependent knowledge and therefore uncertain, rather than absolute like metaphysical knowledge (which is 100% certain, fixed and infallible). Being based on available data that are evaluated and assessed, scientific knowledge is subject to modification in the light of new evidence and new ways of thinking. Nevertheless It is extremely important to understand that science only offer tentative clarification about the functioning of the universe, even then, scientific ideas are still the most dependable account of the nature. In the absence of certainty regarding the absolute truth of scientific explanations, scientists use comparative critical thinking to determine which explanation is better in a number of alternatives. Because it is equally faulty to assume that any and all explanations are equally valid or worthy and that truth is merely a matter of opinion.

7.3 SOME MAJOR CONTRIBUTIONS IN DEVELOPMENT OF SCIENCE IN SEVENTEENTH AND EIGHTEENTH CENTURIES

In this section, we will discuss some important areas of modern science and how they developed in the early modern period.

7.3.1 Developments in Astronomy and Physics

The views of Aristotle and Ptolemy were shattered by Nicholas Copernicus (1473-1543). In his book *On the Revolutions of the Heavenly Spheres* (published posthumously in 1543 because of apprehension of the scorn of fellow astronomers), Copernicus suggested that the sun was the centre of our planetary system and that and planets including earth moved around it in spherical orbits. This Heliocentric conception that the sun — and not the earth — was the centre of the universe contradicted contemporary dominant thinking and challenged the traditional teachings on the subject of hundreds of years. Copernicus' book had enormous scientific and religious consequences. By characterizing the earth as just another planet, he destroyed the impression that the earthly world was different from the heavenly world. Copernicus' ideas influenced others in the field of science. A Danish astronomer, Tycho Brahe (1546-1601), set the stage for the study of modern astronomy by building an observatory and collecting data for over twenty years on the location of the stars and planets. His greatest contribution was collection of huge amount of data, yet his limited knowledge of mathematics prevented Brahe from making much sense out of the data. Johannes Kepler (1571-1630), a German astronomer and assistant to Brahe, used his data to support Brahe's data and Copernicus' idea that the planets move around the sun in elliptical, not circular, orbits. Kepler's three laws of planetary motion were based on mathematical calculations and accurately predicted the movements of planets in a sun-centered universe. His work demolished the old systems of Aristotle and Ptolemy.

The word *scientist* itself was coined in 1840 although the 17th century is revered as an age of great scientific developments. This was the century of Galileo, Kepler, Bacon, Pascal, Descartes, and Newton. They called themselves natural philosophers. Johannes Kepler (1571-1630) lived in a time when astronomy and astrology were conjoined. Johannes Kepler, born in Germany, was a devout Christian (a passionate Lutheran) who was motivated to study science by his belief that God had created the world according to an intelligible plan that is accessible through the natural power of human reason that God had granted human beings. Kepler believed that the world was created by a Creator who used geometry to establish order and harmony, and that this harmony could be explained through musical terms. He thought his Celestial Physics merely revealed God's geometrical plan for the universe. Similarly, Galileo Galilei (1564-1642) was also acquainted with several different fields of science. He did not choose just one specific profession. He was good at playing the lute and the organ, he could draw and paint well.. He studied medicine, explored mathematics and he acclaimed geometry, too. He was also interested in theology too.

In 1608, Europe already had low power telescopes known as spyglasses which is credited to Hans Lippershey, a Dutchman. The magnifying power of these initial telescopes was very limited. There was a captive market for these. Galileo knew about this invention of a new optical instrument. He started designing his own improved versions, with higher magnification. His first telescopes only improved the view to eighth power, but his telescope steadily improved. Galileo's telescope was now capable of magnifying about ten times more than normal vision although it had a rather narrow field of view. The observations with the help of this instrument by Galileo resulted in the discovery of the mountains and craters of the Moon and the moons of the Jupiter's, the descriptions of the stages of the Venus, the drawings of the sunspots which all proved the heliocentric view of the world.

In Galileo's time artillery used cannonballs which were indistinctively made of lead, iron, or other materials and had the same caliber (i.e., diameter), but different weight. Consequently, to standardize the range of the gunfire, the gunner had to adjust the explosive charge in relation to the cannonball utilized. The quantity of gunpowder had to be proportionally greater, in respect to the greater weight. Galileo's compass could be used as a gunner's gauge, because it established the relation between the weight and the volume of the different materials. Using observation rather than speculation to help him formulate ideas — such as his laws on the motion of falling bodies — Galileo established experimentation, the cornerstone of modern science.

He applied experimental methods to astronomy by using the newly invented telescope. His observations using this instrument of the four moons of Jupiter, and a mountainous surface of the moon, destroyed an earlier notion that planets were crystal spheres. It demolished the notion that the earth was the centre of the universe and around it moved separate, transparent crystal spheres: the moon, the sun, five planets, and fixed stars. Galileo's evidence reinforced and confirmed the views of Copernicus. Following the publication of his book, *Dialogue Concerning the Two Chief World Systems* (1632), which openly criticized the works of Aristotle and Ptolemy, Galileo was arrested, imprisoned, tried for heresy (belief or view contrary to orthodox Christian beliefs) by the Papal Inquisition (medieval Christian institution for suppressing the heresy), and forced to publicly repudiate his views. In modern times, Galileo's trial has come to symbolize the conflict between religious beliefs and scientific knowledge.

There was societal and institutional support for scientific works like that of Galileo. Galileo was a prominent member of the famous scientific circle known as The Pinelli Circle. Many well-known people gathered in Giovanni Vincenzio Pinelli's house, where Galilei lived too. Pinelli himself was a humanist in Padua who was interested in several fields of knowledge. In1603, Prince Federico Cesi established the intellectual workshop of the Accademia dei Lincei (The Academy of Lynxes). This demonstrates that patronage from rich and powerful people helped spread of scientific enquiry and a culture supportive of it.

The greatest figure of the century was perhaps Sir Isaac Newton (1642-1727), an Englishman. In his book *Principia Mathematica* (1687), he integrated the ideas of Copernicus, Kepler, and Galileo into one system of mathematical laws to explain the orderly manner the three laws of motion of bodies and his theory of the law of universal gravitation. According to this law, everybody in the universe attracts every other body in precise mathematical relationships and the precise force of this attraction depends on the mass of bodies and distance between them. Newton's law mathematically proved that the sun, moon, earth, planets, and all other bodies moved in accordance with the same basic force of gravitation. Such proof showed that the universe operated by rules that could be explained in the language of mathematics. It is common amongst interpreters of Newton to neglect or even ignore completely Newton's work in alchemy and theology-pretending that it was either a deviation, or at best irrelevant to his most important work. This view makes no senses as Newton's writings shows that he had deep interest in both subjects. This was related in crucial ways to his work in mechanics and optics. Indeed, in his alchemical research he was partly looking for underlying explanations and/or principles which might bear on his discoveries in optics and mechanics. His theological work was part and parcel of his search for general philosophical principles. So his interest in theological matters was not the abnormality of a weird man, but followed naturally from his desire to get to the bottom of things, and find out basic truths about the universe. This may been as argued by some historians that his interest in these questions was precipitated by the necessity for a fellow of Trinity college to be ordained into the Anglican Church, and to affirm his orthodox religious beliefs. Was it simply the question of immediate material benefit in Newton's interest in theology? We should also keep in mind that Newton was living under the influence of a thousand years of Christian religion on the European society of his day.

7.3.2 Mathematics as a Tool

The invention of the logarithm in the early 17th Century by John Napier (and later improved by Napier and Henry Briggs) contributed to the advance of science, astronomy and mathematics by making some difficult calculations relatively easy. It was one of the most significant mathematical developments of the age, and 17th Century physicists like Kepler and Newton could never have performed the complex calculations needed for their works without it. The French astronomer and mathematician Pierre Simon Laplace remarked, almost two centuries later, that Napier, by halving the labours of astronomers, had doubled their lifetimes. The Frenchman René Descartes (1596-1650) developed analytic geometry and Cartesian coordinates in the mid-17th Century. The orbits of the planets to could be plotted on a graph with the help of these. It also laid the foundations for the later development of calculus. Newton and, independently, the German philosopher and mathematician Gottfried Leibniz (1646-1716), completely revolutionized mathematics by the development of infinitesimal calculus, with its two main operations, differentiation and integration. There was a controversy over the claim of its development. Newton probably developed his work before Leibniz, but Leibniz published his first, leading to a long and bitter quarrel. Whatever the truth behind the various claims, though, it is Leibniz's calculus notation that is the one still in use today. Calculus has applications in various fields knowledge engineering, economics, medicine, and astronomy. Both Newton and Leibniz also contributed greatly in other areas of mathematics, including Newton's contributions to a generalized binomial theorem, the theory of finite differences and the use of infinite power series, and Leibniz's development of a mechanical forerunner to the computer and the use of matrices to solve linear equations. In eighteenth century later the Bernoulli Brothers, Jacob and Johann of Basel in Switzerland further developed Leibniz's infinitesimal calculus.

7.3.3 Development in Non-Quantitative Fields

William Gilbert (1544-1603) published a book in 1600,*On the magnet*, which became a standard work on electrical and magnetic phenomena throughout Europe. In it, Gilbert distinguished between magnetism and static (known as the amber effect). He also compared the magnet's polarity to the polarity of the Earth, and developed an entire magnetic philosophy on this analogy. Gilbert's findings suggested that magnetism was the soul of the Earth, and that a perfectly spherical lodestone, when aligned with the Earth's poles, would spin on its axis, just as the Earth spins on its axis over a period of 24 hours. Gilbert was in fact debunking the traditional cosmologists' belief that the Earth was fixed at the centre of the universe, and he provided food for thought for Galileo, who eventually came up with the proposition that the Earth revolves around the Sun. He examined two strictly circumscribed phenomena hitherto immersed in heaps of inaccuracies and folklore, namely, the enigmatic behaviors of pieces of lodestone and of amber, into two distinct, budding branches of specialized inquiry– those of magnetism and of electricity. Gilbert now pooled, checked, and orderly recorded much practice-gained experience gathered by others; established by means of firsthand experimentation numerous other empirical properties of electric and magnetic substances.

William Harvey (1578-1657) was an English physician who had studied at the University of Padua. Harvey's research was furthered through the dissection of animals. He first revealed his findings at the College of Physicians in 1616, and in 1628 he published his theories in a book entitled *An Anatomical Study of the Motion of the Heart and of the Blood in Animals*, where he explained how the heart propelled the blood in a circular course through the body. Harvey was also the first to suggest that humans and other mammals reproduced via the fertilisation of an egg by sperm. It took a further two centuries before a mammalian egg was finally observed, but nonetheless Harvey's theory won credibility during his lifetime.

7.3.4 From Alchemy to Chemistry

Historically, alchemy referred to both the exploration of nature and an early philosophical and spiritual discipline that combined chemistry with metal work. The goals of alchemy were manifold. The alchemists motive was to find the "elixir of life" (a substance with magical properties that would bring wealth, health, and immortality). They also wanted to find or make a substance called the "philosopher's stone," which when heated and combined with "base" (non-precious metals such as copper and iron) would turn it into gold by a process called transmutation. They also wished to discover the relationship of humans to the universe and use that knowledge to improve the human spirit. So, in Alchemy scientific and mysticism merged. With the rise of modern science, alchemists were often projected as charlatans and pretenders. But many alchemists were in fact serious-minded practitioners whose work helped lay the groundwork for modern chemistry and medicine. Alchemists contribution to chemical industries: basic metallurgy, metalworking, the production of inks, dyes, paints, and cosmetics, leather-tanning, and the preparation of extracts and liquors cannot be denied. It was a seventeenth century German alchemist who isolated phosphorus, and another German alchemist of the same period who developed a porcelain material that broke China's centuries-old monopoly on one of the world's most expensive commodities. In 1662, Robert Boyle (1627-1691) articulated Boyle's law, which states that the volume of a gas is correlated to the pressure on it. For this and other important contributions to *scientific inquiry*, Boyle is sometimes called the father of modern chemistry. Like others of his times he called himself a natural philosopher. Boyle wrote two papers on the transmutation of the elements, claiming to have changed gold into mercury by means of "quicksilver," the ingredients of which he did not reveal. He was in this way rooted in alchemy.

Antoine-Laurent Lavoisier was a pioneer who discovered a new chemistry based on experimentation and observation and he made a systematic analysis of his findings. Chemistry was still mired in the legacy of the alchemist as we have seen from the example of Boyle. Even the simple process of combustion or burning of any substance in air was not clear even at the beginning of eighteenth century. German scientist Georg Ernst Stahl early in the 18th century believed that everything that burned contained a common element of fire. He named this element *phlogiston*, derived from a Greek word for ignitable material. Sthal's experiment found that charcoal lost weight when it burned. Stahl believed that any material lost when burned and this was the proof of the fact a substance lost weight when burnt because of the loss of its phlogiston element in the air. Since there was no solid explanation in those days about the phenomenon of burning, explanation, people accepted readily it. Lavoisier conducted experiments with phosphorus and sulfur, both of which easy to burn and Lavoisier found that they gained weight by burning in the air. This was contrary to Sthal's hypothesis on burning or combustion. Using *lead calx* for his experiments (a substance formed from an ore or mineral when heated or oxide of a metal in modern language of chemistry), he was able to show that it gained in weight when burned, probably because it combined with air and same air was released when the *calx* or lead oxide was heated. This made Lavoisier doubtful of the existence of *phlogiston*. Although Lavoisier now realized that burning or combustion actually somehow involved air, but since he was still ignorant about the exact composition of air, he could not go any further. In August 1774, the famous English scientist Joseph Priestley met with Lavoisier in Paris. He shared his experience about his experiment of heating mercury *calx* in which a gas was obtained in which a candle burned more easily. Priestley believed that this 'new gas' helped in burning and caused candles to burn longer because it was free of phlogiston. For this reason, he called the gas that he obtained by burning mercury *calx* "dephlogisticated gas".

In Paris, the inquisitive Lavoisier repeated Priestley's experiment with mercury and some other metal oxides. His conclusion was that the air was a compound of many elements or gases. At least, he argued, there were two components: one that reacted with the metal and helped the process of burning and the another that obstruct burning process. By 1777, Lavoisier proposed a new theory of burning or combustion that rejected the Sthal's notion of existence of phlogiston. Combustion or burning was explained as a chemical reaction of a combustible metal or an organic substance with that part of common air that helped in the process of burning. In 1779, he announced to the Royal Academy of Sciences in Paris that he found in his experiments that most acids contained this type of air. Lavoisier named it *oxygène*. So the Stahl's *phlogiston* was imaginary. In new theory of combustion oxygen now played the central role.

In 1766, Englishman Henry Cavendish obtained a gas that burned easily. Priestley noted that when gas obtained by him and common air were burned with a spark in a closed container, a small amount of dew-like substance was found on the walls of glass container. When Cavendish repeated the experiment, he found that this dew like substance was actually water. Cavendish still interpreted the findings of his experiments in terms of phlogiston and thought the water was present in each of the two airs before the process of burning. Lavoisier explained that burning or combustion involve chemical reaction with oxygen; however, until he could explain the combustion of new gas obtained by Cavendish, some would still doubt his new chemistry. In June 1783, Lavoisier combined oxygen with Cavendish 'new gas', and obtained water. His conclusion was that water was not an element but a compound of oxygen and Cavendish's 'new air', which we now know as hydrogen. To support his claim, Lavoisier decomposed water into oxygen and hydrogen. Now that the chemical composition of water was known, the last doubt to throwing away phlogiston hypothesis was removed. Lavoisier adopted the long-neglected idea of an element as originally proposed by Robert Boyle more than a century earlier. They retained the names from the past of many simple substances, or elements. But when an element combined with another element, the compound's name now reflected something about its chemical composition. Lavoisier's new chemistry, expounded in his *Elements of Chemistry* (1789) incorporated many new aspects like the impact of heating on actual chemical reactions, the exact nature of gases, various chemical reactions of acids and bases which combined to form salts, and the description of various apparatuses used to perform chemical experiments in laboratories. Lavoisier defined the Law of the Conservation of Mass in the following words "... in every chemical reaction an equal quantity of matter exists both before and after the chemical reaction. He also listed the then-known elements.

Check Your Progress 1

1) Describe the contributions of natural philosophers in the development of astronomy and physics in seventeenth century.

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2) Discuss the development of science in non-quantitative fields in seventeenth and eighteenth centuries.

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7.4 INTERPRETING SCIENTIFIC DEVELOPMENTS OF SEVENTEENTH AND EIGHTEENTH CENTURIES

The scientific development of the seventeenth and eighteenth centuries have been interpreted in many ways by scholars. In 1943 the French historian Alexandre Koyré described the scientific advance of seventeenth and eighteenth centuries as a quantum jump or qualitative break with the past pattern of human thinking. For him, it was the most insightful development in human thinking, a real revolution created by the human mind since Greek antiquity. It made fundamental changes in human culture and way of life and left a permanent mark on the human mind. Later, the English historian Herbert Butterfield also termed it as a major revolution, something spectacular since the rise of Christianity. According to him, compared to this great epoch making transformation, the Renaissance and Reformation were simple episodes in the history of humankind. He emphasised that this Scientific Revolution was the real origin of the modern world. These early historians of science, thus, depicted it as a consistent, pioneering revolution event that profoundly and without end altered human perceptions of the universe and ways and means by which human beings interacted with nature and environment. It was the singular moment for the entry of modernity in our lives. at which the world was abruptly made modern. It was a libertarian in the sense that it removed superstitious and irrational way of thinking that had persisted for centuries.

We have mentioned earlier that although many seventeenth century practitioners expressed their intention to bring about a radical intellectual change, they used no term such as Science or Revolution to refer to what they were doing. They called themselves natural philosophers and many of them were interested in issues and problems of theology, some were immersed in practices of alchemy. So many historians find the idea of a Scientific Revolution an uneasy one. Many historians are now question and criticize that there was sudden and catastrophic change that occurred in Western Europe, particularly in the fixed time period of seventeenth or eighteenth century that can be marked as the Scientific Revolution. There are also doubts about the cultural notion science manifested in a unique manner in the seventeenth century. Now scholars argue science was involved in cultural practices which found expression in a variety of ways and that there can be a large number of ways and methods through which human beings can aim to understand, explain, and control nature and environment. Every Method may emerge in a particular cultural setting and can have its own features and may herald a different kind of change in human thinking and perception. There cannot be a unique and single method to obtain knowledge which is universal or eternal of all times and all places. The so called scientific method— a consistent, universal, and efficient manner of creating knowledge that can be traced in the seventeenth is a cultural specific product, they argue. The seventeenth-century's knowledge systems was only a continuation of medieval knowledge systems. It did not emerge in a vacuum. We cannot assert with certainty that medieval world ceased to exist at this particular point or from this particular time period modern way of thinking became the hallmark of human consciousness and perception. The seventeenth century scientific practitioners often believed and practised in certain cultural practices what we may perceive as 'medieval' or 'modern'.

Some historians argue that the idea of scientific development must be situated in the wider cultural and social context of seventeenth and eighteenth century. in other words, they feel that the scientific changes of the seventeenth century must be interoperated in the context of changes in socio-economic, political, and cultural conditions or patterns of thinking. More importantly, some historians now wish to understand the development of scientific endeavour in the concrete historical circumstances of those times. What actually transpired and what was the social cultural milieu of the period when a particular mode of science was taking root? How did the institutions help in obtaining and creating scientific knowledges and how this base expanded with the passage of time? These are important consideration of historians of science. Some historians analyse the actual stories of people who wrought such changes? We have seen that there were prominent circles patronized by the rich and powerful people in the seventeenth century and later institutionalization of scientific efforts in the form of various academies etc. It is important to see that modern science emerges at a time when the institutions of the Middle Ages, such as the Church, the universities and the established professions of jurisprudence, theology and medicine, were declining but when the social and political order of modern society had not yet consolidated. It was in this period of transition and turmoil that modern science emerges. However, by the late seventeenth century with the growth of powerful monarchs in some countries of Europe, they tried to use it for their own purpose. The Restoration government in England in 1660s purged the reformed universities of the adherents of the new experimental natural philosophy and re-established the authority of the Church and state. This period was also the period of the institutionalization of science under the patronage of the absolute state. This was marked by the foundation of the Royal Society in London in 1662 by Charles II, the Academic des Sciences in Paris in 1666 by Louis XIV. and the Akademie des Wissenschaften in Berlin in 1700. The political integration of science by royal edicts into the state compromised its radical function.

The American sociologist, Robert K. Merton, is the main pioneer of the sociology of science. His studies focused on sociological aspects of the scientific enterprise. His thesis, “Science, Technology and Society in Seventeenth-Century England”, demonstrated how Puritanism unintentionally provided social and cultural support for the science emerging in 17th -century England. He used massive amount of statistical and historical data to support his cautiously drawn conclusions that Puritanism provided a system of values and beliefs which fostered the development of seventeenth-century English science. Edgar Zilsel, an Austrian philosopher/scientist, adopted a more moderate economic-deterministic approach in his researches. He propounds the idea that the early capitalistic society broke down the ancient barriers separating the scholar from the craftsman, or what George Basalla (1986) identified as the 'man of formal knowledge' from the ´man of practical knowledge'. From antiquity through the Middle Ages, the philosopher and the priest were socially superior to the metallurgist, potter, ship-builder, or other craftsman. On the different extremes the scholar excelled in logic, speculative thinking, and mathematics while the craftsman has a special knowledge of the material objects. Hence, theory and practice were separated for centuries until the needs of an emerging capitalistic society joined them together to produce modern science.

Sometimes the traditional account of the development of science in seventeenth and eighteenth century read like the celebrations of the heroic achievements of

Great Men (not women!) making or creating Modernity. So what where are the voices of lesser participants (and sometimes of the laity). What were their reactions? Were they passive spectators? How did the forms of culture traditionally considered peripheral to, or even outside the 'science proper.' react or adapt to new mode of thinking prevalent in 'scientific circles'? As a result of questioning subjects and/or people previously left wholly or partly in the margins have come to be included in the narrative. Examples are subjects that (at the time) were nonmathematical and chiefly descriptive, like magnetism and illness; subjects that are scarcely practiced anymore, like musical science, and/or are held under grave suspicion, like alchemy; but also previously neglected contributors not of the first or even quite the second rank (e.g., hosts of ably experimenting Jesuits). Some people argue that the use of quantitative methods and mathematics was really novel and important in the seventeenth century. This really destroyed the centuries old Aristotelian notions of the universe and nature. If we agree with this viewpoint then naturally individuals like Galileo, Descartes, Huygens, and Newton extremely important. The traditional approach towards scientific developments emphasizes mathematical physics and astronomy. It is true that some significant developments did take place in the field of astronomy and physics but that was not entirely which constituted the Scientific Revolution. However, not all seventeenth century natural philosophy was mechanical or experimental. Nevertheless, the role of Mechanics in knowing about the nature certainly increased, and there were scientific disputes about the correctness of tools of mechanical and experimental methods in acquiring knowledge. These to some extent capture what is valuable in understanding about cultural change in this period.

Science can be understood only its historical context and we can understand the scientific works only in the cultural context in which they are created. Historians have long argued about the role of historical and social contexts in knowing about the process of development of a particular branch of science. Certainly, its development cannot be visualized in isolation from such context. The Science in seventeenth and eighteenth centuries was a collectively practiced, historically embedded phenomenon. So when sociological and historical context is accepted by scholars, they draw less attention to intellectual history of ideas, concepts, methods, evidences in themselves but emphasise more on the social factors like institutional form of scientific works, the role of socio-economic factors in development of science, and practical social uses or implication of scientific development for overall societal development . There is room for contingency in the story – not everything that happened was bound to happen, or was bound to happen the way it did happen. Historians of science have further become aware that there were more significant reasons for contemporary perceptions of modern-science-in-the-making as innately strange and disturbing than sheer backwardness and/or superstition. So we feel that multiple stories can be told about the scientific development of seventeenth and eighteenth centuries.

7.5 WOMEN AND MODERN SCIENCE

If we look for women in state sponsored Academies of Science, there was not a single woman as member in them in seventeenth and eighteenth centuries but they were not absent completely from scientific fields. We come across one German astronomer Maria Winkelmann. Again Winkelmann was not the only one. It has been estimated that out of all German astronomers working in the early eighteenth-century, 14 percent were women. In 1710, Maria Winkelmann petitioned the Berlin Academy for an appointment as assistant astronomer and calendar-maker when her husband and Academy astronomer (*Gottfried Kirch*) died. She was as a seasoned astronomer who had published astronomical observations under her husband's name while he was ill and dying. Although the great Leibniz, then President of the Academy, supported her claim, her request was denied. Then another interesting example is that of Laura Bassi (1711-1778), first woman to become a professor of physics at the University of Bologna in eighteenth century. It is amazing to note that she had twelve children. Did they not interfere in her scientific productivity? She published her studies on electricity and air pressure etc regularly. what made it possible? We know that in Europe, the child rearing practices for the upper classes made this possible. Soon after the birth of a child, it was handed over to a governess or wet nurse and reared in the countryside. A upper class mother might not see her child again until age of seven and about that age boys were sent to boarding schools. So probably this prerogative of a upper class woman allowed an uneasy fix between reproduction and her professional life. Yet the basic fact remains that modern science and professional life was not meant to be for women in the prevailing man-dominated society.

Check Your Progress 2

1) Critically evaluate the various interpretations of the scientific development of seventeenth and eighteenth centuries.

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2) Explain the role of Women in Science in seventeenth and eighteenth centuries.

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7.6 LET US SUM UP

In this Unit, we have seen how the modern science as we know it germinated, how it spread to various fields and how nature-knowledge of one field was not entirely independent. The nature-knowledge of one kind was dependent on the others and the cumulative impact of these interactions made it sustainable in long-run. Although society and its culture was changing, the outlook and temperament was of the key figures of the seventeenth and eighteenth centuries was still immersed in the medieval ideology and theology. It was not a complete break with the past. As was expected, women remained on the margin in this discovery of nature-knowledge. Various interpretations of these developments has been offered but it appears a number of stories are possible.

7.7 ANSWER TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress 1

1) See Sub-section 7.3.1
2) See Sub-section 7.3.3

Check Your Progress 2

1) See Section 7.4
2) See Section 7.5