8 Scientific Revolution of 16th and 17th Centuries

The breakthroughs of the 16th and 17th centuries have been described as the Scientific Revolution, but that is somewhat misleading if it is assumed that the term implies a rapid, widespread transformation of society

However, the development of science was a slow process that only included several hundred people

Since the term scientist hadn’t been developed until the 1830s, these persons considered themselves as natural philosophers

Although some of these natural philosophers depended on artisans and craftspeople, and some even worked at universities or had the patronage of kings, the majority pursued their studies privately

It was not until after the middle of the 17th century that learned societies and academies were established to promote research

Despite the general casual approach to scientific work, by the end of the 17th century, the new scientific concepts and methods that emerged were so impressive that they set new standards for assessing the validity of all knowledge in the West

This development was so significant that modern science became one of the defining characteristics of Western Civilization

Interestingly, the discipline that did most to initiate these developments was astronomy

Nicolaus Copernicus, an Italian-educated Polish astronomer published a book titled *On the Revolutions of the Heavenly Spheres* in 1543, the year of his death

The book did not create a revolution, but it did lay the groundwork for a revolution by providing later scholars with a springboard for a criticism of the previously accepted view of the position of the earth in the universe

The maps of the universe at the time were based on the thinking of the ancient Greek astronomer Ptolemy (150 A.D.) and his book *Almagest*

It was assumed that the earth was the center point of a round universe composed of concentric, rotating spheres to which the plants and the stars were attached

Beyond the limits of these spheres lay the realm of God

The assumptions about the laws of physics were the basis of Ptolemy’s model of the universe

The earth was thought to be the heaviest object and so it sat at the center of the universe

Although medieval astronomers were aware of problems with this understanding of the universe, they were able to explain the anomalies identified by observers

For example, the planets didn’t always move in circular orbits

This was explained by a theory that the planets traveled on the spheres in shorter cycles, as they travelled the larger cycles

Copernicus sought to propose a refinement that would better explain the anomalies associated with Ptolemy’s universe

Copernicus suggested that this problem could be corrected if one understood that the earth orbited the sun

Thus, when the earth made an orbit around the sun, it made the other planets seem like they were moving within their own cycles

In other words, that observation was an illusion

Other than that, Copernicus accepted the Ptolemaic system

The Copernican model was slow to attract followers, and the initial importance of his work was that it encouraged people to think differently about scientific problems

In the meantime, Tycho Brahe, a Danish astronomer, sought to refute Copernicus in an effort to defend the Earth-centered model of Ptolemy

He argued that the moon and the sun revolved around Earth and that the planets revolved around the sun

To make his case he collected the most accurate data ever acquired

When Brahe died, Johannes Kepler, a German astronomer and supporter of Copernicus, figured out that if the planets were traveling in elliptical orbits around the sun, then Brahe’s data supported the Copernican theory that everything revolved around the sun

Kepler published his findings in 1609 in a book called *The New Astronomy*, but he couldn’t explain why the planets orbit shape remained fixed

This had to await the theory of gravity

Up to this point all astronomical data had been acquired by the naked eye

In 1609, the year of Kepler’s book, an Italian scientist Galileo Galilei used a Dutch invention called a telescope to view the heavens and saw things that had never been seen before

Galileo saw that moons orbited Jupiter among other things and argued that the Copernican model best explained what he had observed

Galileo worked for the court of the Medici Grand Duke of Tuscany and his job was to enhance the reputation of his noble patron

Therefore, he published his findings in accessible treatises which made him the leading advocate for the Copernican model of the universe, and it caused him problems with the church

Galileo popularized Copernicanism and he also promoted the idea of a universe governed by rational laws as stated in mathematical formulas

This emphasis encouraged scientists to look for explanations of things by focusing primarily on phenomena that could be quantified

Mathematical models were applied to explain everything including non-physical subjects such as social relationships and political systems

From this perspective nature appeared to be a mechanistic system

Only things that were measurable seemed real and of lasting significance

This attitude brought a major intellectual shift to Western Civilization

Copernicus, Kepler, and Galileo could not explain why the heavenly bodies moved in on orderly fashion

It was Isaac Newton in England who made the discoveries that explained this phenomenon

In 1687 Newton published *The Mathematical Principles of Natural Philosophy* (*Principia Mathematica*)

Newton had been influenced by Galileo’s insight that reality could be described mathematically

Galileo’s insights into inertia especially influenced Newton

Earlier scientists thought that rest was the natural state of an object, and that motion had to be explained

Galileo proposed instead that what scientists should ask was not why there was motion instead of rest, but why is there a change in existing state, be it rest or movement

Newton theorized that the revolutions of heavenly bodies were controlled by gravity or a pull that every physical object exerts on the objects around it

Since the strength of this attraction is proportional to the mass and proximity of each object, the order that exists among the planets can be explained as the balance they have achieved among mutual forces

Newton demonstrated the effects of gravity mathematically, but he made no attempt to explain what gravity was in itself

Newton also argued that the ultimate test of a theory was its ability to explain empirical data and observation

Science focused on empirical observation, not with a rational argument about what ought to be there

The revolution taking place in science encouraged a major rethinking of the Western philosophical tradition

The religious beliefs of the medieval Scholastics were abandoned in favor of a world described in terms of mechanical metaphors and the language of machinery

Philosophers had previously assumed that an understanding of the natural order would reveal divine mysteries and transcendent insights, but the modern scientific conclusion was that knowledge of nature revealed nothing beyond itself

Such knowledge might lead to physical improvements, but it could not disclose a divine purpose for life

Francis Bacon, the person who is honored as the father of the modern scientific method of research, was not a scientist

He was an English lawyer, statesman, and author

Bacon published works that attacked medieval Scholasticism’s reverence for authority (mainly the Church)

He urged people to strike out on their own to search for an understanding of nature

He argued that knowledge was not just an end, but that it should produce useful results

If progress was to be made, scientists would have to rely on empirical observation rather than logical speculation

Only through this approach would new information be discovered opening new possibilities for humanity

Bacon’s rejection of past methods of inquiry came from his awareness that the world was becoming more complicated (less traditional?)

He anticipated a future of material improvement and more effective government achieved through the empirical examination of nature

Empirical observation is based on inductive thinking

Reasoning in which the conclusion, though supported by the premises, does not follow from them necessarily

Generalizations are derived, not from the truths of the premises, but from observations

René Descartes, a French mathematician, relied more on deductive reasoning

Deductive reasoning is a process of reasoning in which a conclusion necessarily follows from the premises, so that the conclusion cannot be false if the premises are true

Descartes tried to put all human thought on a secure mathematical footing

He said it was necessary to doubt all ideas except those that were clear and distinct

Any idea was worthy of trust not because some authority vouched for it but because all rational beings could intuit its validity for themselves

A good example of Descartes’ premise oriented deductive thinking is as follows:

Descartes began his search for truth by seeing if he had any ideas that he could not doubt

He concluded that it was not possible to question his own act of thinking without assuming that he existed

To doubt doubting, one could not doubt the existence of the doubter

With this clear and distinct idea as his premise, he was able to construct arguments deducing the existence of God and the real world external to the human mind

Descartes divided existing things into two basic categories, things in thought and

things in space

Thinking was characteristic of the mind

Things occupying space were of the body

Since space was measurable by math, mathematical laws governed that world

Spirits, divinities, or immaterial things of the mind belonged to the scientist using, not mathematical means, but mathematical reason to discover the properties of that world

Natural scientists eventually abandoned Descartes deductive reasoning in favor of induction

However, deduction has remained popular in subjects or disciplines for which empirical data is considered inconvenient regarding accepted premises

The modern social sciences are a good example of a subject area that employs deductive reasoning

The most original political philosopher of the 17th century was Thomas Hobbes of England

Hobbes spent time with Descartes and with Galileo, as well with William Harvey, the person who discovered that blood circulated through the human body

The English Civil War inspired Hobbes to become a political philosopher and he published a book titled Leviathan which offered a mechanical understanding of human behavior

Hobbes theorized that all psychological processes derived from sensation and that all motivations are egotistical

Thus, the driving force in humans is to maximize pleasure and to minimize pain

There are no higher spiritual ends, and there is no great moral purpose

People simply strive to meet the needs of their daily lives, and in order to do so they have to form a government in order to prevent a society of egoists from tearing themselves apart

Hobbs saw that nature set people in a perpetual desire for power and that created a continuous war of everyone against everyone

Whereas earlier philosophers saw the original human condition as a paradise from which humans had fallen, Hobbes saw human nature as corrupt that could only be tamed by the establishment of a politically organized society

People could escape their natural state by entering a social contract ruled by law

The fear of death is what compels humans to enter into this contract

The social contract obliges every person to agree to set aside their right to all things and to be content with as much liberty against others as they would others against themselves

Because words or contracts are insufficient to guarantee this agreement, the social contract authorizes the use of force to compel compliance

Believing the dangers of anarchy were greater than tyranny, Hobbes thought that rulers should have unlimited power

He didn’t care what form governments took as long as there could be no challenge to authority

Again, Hobbes’ philosophy was influenced by the English Civil War

He insisted that the loss of rights of some individuals was preferable to the suffering that everyone experienced in a civil war

On the other hand, another Englishman, John Locke was the most influential critic of political absolutism

Locke was sympathetic with the leaders of the English Civil War and the Glorious Revolution

During the reign of Charles II, not only did Locke join a rebellion against the king, but he also wrote to treatises against absolutist government

The first was a critique of the traditional arguments for absolutism

Absolutists tried to justify their position by comparing it to the roles that fathers play in patriarchal families

(Authority traditionally based on kinship)

Locke argued that both fathers and rulers are bound by the law of nature that creates everyone equal and independent

In the second treatise, Locke made the case for government’s obligation to be responsive to the wishes of the governed

He disagreed with Hobbes’ assumption that people were driven by passion and selfishness

Locke argued that humans were endowed by nature with reason and good will

People could cooperate and live together in peace on their own, but they established governments to solve problems and to facilitate social life

Governments are based on social contracts that are meant to protect the liberty of the state of nature, not to restrain it

Rulers who fail to honor the terms of such contracts can legitimately be replaced by their subjects

Locke held that governments should limit themselves to protecting property and should not make religious decisions for their people

He argued that each person is responsible for their own salvation

Locke denied religious liberty to atheists on the grounds that they could not be trusted, and to Catholics on the grounds that they served a foreign prince (pope)

In 1690 Locke offered a scientific explanation of human psychology

Locke claimed that the mind of newborns was a blank slate, and that no knowledge was innate

Everything came from sensory experience and that human beings were products of their environments

The slowness of the universities, where traditional scholastic and Aristotelian thinking was entrenched, to assimilate modern scientific advances, persuaded scientists to create new institutions to advance their work

Most prominent of these institutions was the Royal Society of London, founded in 1660

These institutions promoted research and the sharing of information

Similar organizations were established all over Europe

Members of these societies were from the intellectual elite, but they cooperated with craftspersons and sailors whose experiences made them important sources of aid and information

These learned societies were eager to demonstrate what science could do in order to solve problems of government and economic life

Persons who had ideas to improve such things as navigation, agriculture, engineering, and military technology could turn to the societies for support

And the patrons of the new sciences sought to apply scientific knowledge to practical ends urging religious toleration and political liberty

Women generally did not participate in these scientific endeavors mainly because traditions accepted by men and women excluded them from these pursuits

However, there were very few exceptions

Margaret Cavendish, Duchess of New Castle, was the only woman allowed to attend the Royal Society

She published scientific treatises, debated the theories of Descartes and Hobbes, and published a text intended to introduce women to the study of science

Women from the artisan ranks generally had more access to practical science as they assisted their husbands in their businesses

Several German astronomers were assisted by their wives and daughters and a few of them wrote book and made discoveries on their own

For example, after the death of her husband, Maria Winklemann discovered a new comet in 1702

In the 1730s, the French philosopher Voltaire relied on the mathematical expertise of Emilie du Châtelet for help in writing a book on Newton

Many believed that the new science posed a challenge to religion

Three issues became problematic

1. Disagreements between the Bible and scientific discoveries
2. The relative authority of the clergy versus scientists
3. The tendency of scientists to promote an exclusively materialistic view of nature

In 1633 the Catholic Church condemned the Copernican theory and Galileo

The Council of Trent had asserted that the Church alone had the authority to interpret the Bible

Galileo’s views on the Bible seemed to challenge the official interpretation and his discoveries supported Copernicus’s theories that the Church declared as unbiblical in 1616

When Galileo was allowed by the church to publish his research in 1632, Pope Urban VII felt threatened by the work and ordered Galileo investigated

Galileo was forced to repudiate his theories and was place in house arrest for the last nine years of his life

Blaise Pascal, a French mathematician, and scientist made the greatest attempt to reconcile faith with the new science

Paschal was deeply religious and sided with the Jansenists

He argued that reason could reveal the corruption of humanity, but that reason was too weak to resolve the problems of human nature or to disclose the meaning of life

A leap of faith was required to accept that religion operated outside of the domain of reason

Pascal famously noted that it is better to believe in God than to doubt the existence of God

If God exists, then the believer wins everything

If God does not exist, then nothing was lost by believing

He also argued that faith is valuable in and of itself apart from the issue of the existence of God

It provided motivation for self-discipline and moral character

In England, Francis Bacon reconciled religion and science by suggesting that the Bible and nature were both sources of divine revelation since both were created by God

It was only logical to assume that the knowledge they produced would ultimately be discovered not to be incompatible with itself, and that one could be expected to illuminate the other

Newton came to believe that the rational laws that governed nature implied that nature’s creator was also characterized by rationality

To study nature was to study the Creator and to move from knowledge of phenomena to knowledge of their ultimate cause

Faith in a rational God also encouraged faith in human rationality and humanity’s ability to overcome the errors of its past

The new way of life that began to emerge from the new science was justified as part of a divine plan

God had place rational beings in a rational world so they should master it

Based on this thinking, scientific advance and economic enterprise became religious missions of sorts

Despite the confidence certain Europeans had in the triumph of reason, most people throughout the continent continued to live traditional lives and maintained their strong belief religion and in various supernatural claims

The period from 1400 to 1700 was an era of great and transformative developments and changes

These developments and changes challenged people’s traditions and their traditional approaches to life

These challenges were oftentimes perceived as a direct threat to the ability of people to protect and provide for themselves

During the span of these decades, some 70,000 to 100,000 persons were accused and executed as witches

What was going on here?

These types of accusations and murders are seen around the world and throughout time, including today

However today people are oftentimes scapegoated for non-religious, yet non-observable or verifiable claims

These changes of this period were perceived as threats to stable practices of society

For example, the Protestant Reformation created all kinds of threats to social stability in places throughout Europe

Likewise, the scientific revolution challenged people’s traditional understanding of nature and caused anxiety as people perceived being threatened by the new knowledge

Situations like this can cause people to seek to restore stability and enforce cooperation through the accusation of an innocent person of supernatural crimes or activities

Oftentimes the innocent victim is a woman that is generally alone or without the protection of family, husbands, brothers, or sons

Other vulnerable persons, such as unrelated servants, beggars, loners, and such were also accused of these supernatural crimes

That the great witch panics of Europe occurred in the late 16th and 17th centuries suggest that the great divisions splitting Europe apart during the Protestant Reformation and the Counterreformation, the wars of religion, the 30 Years War, the English Civil War, and the Glorious Revolution, and the challenges of science to the traditional way of life, were a great source of these panics

The witch hunts helped community, church, and state enforce conformity and eliminate competition for the loyalty of neighbors, parishioners, and subjects

By the end of the 17th century authorities perceived that this behavior was doing more to destabilize society than to impose order and unanimity

Nevertheless, the era of the scientific revolution was a major turning point in the history of Western Civilization and the world

Many fundamental premises of the medieval were being abandoned

Traditions were being displaced

Authority of the church was challenged

Individualism was promoted

Political thought forced on greater individual freedom and political expression