March 8, 2016

The Social Context of the Scientific Revolution

In this lecture, we will look at technological, economic, religious-cultural changes in Western Europe in the five centuries leading to the scientific revolution in the 16th to 17th centuries.

The following is the rough timeline of the six developments we will look at:

The Translation movement in Europe 10 c onward

Renaissance Humanism end of 14th – 16th c

Invention of the printing press by Gutenberg 1450

The discovery of the New World by Christopher Columbus 1492

The Protestant Reformation 1517

“Craftsman-scholar” Throughout this period

The Translation Movement in Europe: From Arabic and Greek into Latin

The reports of Greco-Arabic texts in the Arab-controlled countries, especially Spain and Sicily aroused the curiosity of Christians in the Western part of Europe. This led to many expeditions into Muslim controlled parts of the world.

The Western Crusades against Muslims in Spain resulted in the fall of Toledo (Spain) in 1085, and it was from that time that the Arabic version of Greek scientific works were translated into Latin. Between 1125 to 1200, there was a flood of translations. Spain was the most important part of the contact between Christians, Muslims and Jews, many of whom were bi- or even tri-lingual, speaking Latin, Greek and Arabic.

The most important translator from Arabic to Latin was **Gerard of Cremona (1114-87).** He went looking for Ptolemy’s *Almagest*, which the Latins had heard about , but had no copy of. He went to Toledo, there he learned Arabic language and translated the *Almagest* into Latin. He did not stop there: he translated some 70 other texts from Arabic into Latin, including the basic works of Aristotle (Physics, On the Heavens and World, On Generation and Corruption, and Meterology), as well as Aristotle’s works on logic and scientific method. He also translated Euclid’s Geometry and the Algebra of the Arab mathematician, al-Khwarizmi. In addition, he translated a large number of medical texts, including many by Galen, as well as notable works by Arabic doctors and philosophers

In addition to Arabic-Latin, translations were also made between Greek and Latin texts.

Just like the Arab scholars had gone to distant lands to look for books, scholars from the Latin-speaking Europe also went looking for books in old churches and monasteries which often had saved one or two copies of ancient Greek texts.

Renaissance Humanism

 The dictionary meaning of **Renaissance** is simply “rebirth.”

Historically, the period of *Renaissance* refers to the cultural movement that spanned the period roughly from the 14th to the 17th century, beginning in Italy and later spreading to the rest of Europe.

What was this cultural movement seeking “rebirth” of ?? What exactly was to be reborn?

The renaissance was seeking a rebirth of the classical heritage of Greece and Rome.

As we have seen, from around 1000 CE onwards, medieval churchmen had been gradually rediscovering and integrating the ancient works – but these works were treated as handmaids to the Bible, i.e. used only to re-affirm the Christian teachings.

Renaissance went beyond the Scholastics: rather than Christianize the pagans, Renaissance humanists saw value in all literary classics of antiquity regardless of whether they supported or challenged Christiantiy. All the classics of the antiquity – poetry, essays, letters, histories, biographies, art, architecture, sculpture… were embraced on their own terms, without needing any Christian modifications. The idea was not to copy the ancients, but to bring back the same moral and imaginative fire that had supposedly inspired the antiquity.

What did renaissance mean for science? restoring the spirit of Aristotle, math of Archimedes, the astronomy of Ptolemy, the …

 The invention of the printing press

Gutenberg printing press has been cited by many as the most important invention in all of the last millennium.

Around 1450, Johannes Gutenberg invented the printing press and independently developed a movable type system in Europe. Gutenberg was the first to create his type pieces from an alloy of lead, tin, and antimony —the same components still used today.

For alphabetic scripts, movable-type page setting was quicker and more durable than block printing. The metal type pieces were more durable and the lettering was more uniform, leading to typography and fonts. The printing press was especially efficient for limited alphabets (as in the English language, as compared to the Chinese who were also trying movable type.)

The printing press displaced earlier methods of printing and led to the first assembly line-style mass production of books.A single Renaissance printing press could produce 3,600 pages per workday, compared to about 2,000 by typographic block-printing and a few by hand-copying. Books of bestselling authors such as Luther and Erasmus were sold by the hundreds of thousands in their lifetime.

Printing soon spread from Mainz, Germany to over two hundred cities in a dozen European countries. However the first book in English was not until 25 years later in 1475. By 1500, printing presses in operation throughout Western Europe had already produced more than twenty million volumes

By 1500, there was already one printed book in existence for every five living Europeans.

Printing’s relevance to **science**

1. Wide availability of a variety of philosophical schools; intellectual life no longer tied to either the universities or the church. A new culture of coffee houses started, esp. in England where ordinary people would gather together to read pamphlets, magazines. Even members of the Royal Society were known to gather in coffee houses to debate and even demonstrate their experiments.
2. Vernacular texts, especially in Italian and German. You needed literacy, but not scholarly training in Latin in order to learn …
3. “Book of secrets” and “little craft books”: medical books, alchemical, pottery, ceramics etc. these highly popular booklets did two things: broke the monopoly of craft guilds; and “lifted the veil of mystery” so that ordinary people could see that the craftsman was not possessed of some arcane wisdom, but simply knew some techniques that anyone could apply. (Dear 26)
4. Diagrams in scientific texts. “The simple ability to juxtapose and compare reliable representations of competing theories revolutionized the possibilities for learned work.” (EnC)

Discovery of the New World by Christopher Columbus in 1492

 Christopher Columbus and his crew reached the Americas on October 12, 1492. During four separate trips that started with the one in 1492, Columbus landed on various Caribbean islands  that are now the Bahamas as well as the island later called Hispaniola. He also explored the Central and South American coasts. But he didn’t reach North America, which, of course, was already inhabited by Native Americans.

Columbus had set out to find a Western route to India, China and Japan from Spain. Europeans had been traveling to Asia either through the land route (the famous “silk road”) or through a sea route through the southern tip of Africa (the Cape of Good Hope) which connects the Atlantic to the Indian ocean. Both of these routes were blocked to the Spanish for political reasons. So they were interested in a new route to Asia.

The discovery of the new world started a new era of exploration, trade and colonization. All major European powers tried to establish colonies in the Americas. The native populations who had lived on the Americas for many centuries suffered greatly: they were enslaved, made to convert to Christianity and many died due to exposure to new diseases brought with them by the European colonizers.

Back in Europe,, the discovery of the new world posed new challenges. Suddenly, the Spanish, Portuguese, Dutch, English and French were encountering people, plants and animals they had never seen before. It also challenged the force of tradition and authority. People began to wonder why the Bible knew nothing of the New World. That made them wonder what else the Bible did not know? Could they accept it as a true account of the world? It also sparked curiosity and a spirit of exploration. s

The Protestant Reformation

The **Protestant Reformation** was a major 16th century European movement aimed at reforming the beliefs and practices of the Roman Catholic Church.

The Reformation began with Martin Luther (1483-1546), a German Christian monk challenged some practices and doctrines of the Catholic Church. Luther believed that the Catholic church had become corrupt, superstitious and power-hungry. He was especially angered by the practice of the Church through which you could seek forgiveness for all your sins and assure a place in haven by making donations to the Church. So, in 1517 Luther, famously, nailed his 95 theses on a church door in the university town of Wittenberg. That act was common academic practice of the day and served as an invitation to debate. Luther's propositions challenged some portions of Roman Catholic doctrine and a number of specific practices. (There were other reformers, apart from Luther: John Calvin and Ulrich Zwingli in Switzerland.)

The reformers challenged the idea that god’s favors can be bought by making donations to the Church. they insisted on going back to the original teachings of the Bible that God is all powerful: only God can CHOOSE whose sins to forgive, whose souls to save etc. God, they said, can’t be manipulated by buying and selling his grace. Faith alone – and not any worldly power – can provide salvation.

The reformers believed that a return to the original teachings of the Bible was needed to cleanse the CHruch of all its corruption. To follow the Bible, moreover, there was no need for any intermediaries: no priests, no rituals. Every person was to be his or her own priest and read the Bible directly.

The message of the Reformation spread like wild-fire throughout Europe, in part because of the printing press. Luther’s theses were printed as pamphlets, translated into local languages.

The Reformation will have a great influence on the Scientific Revolution, as it provided arguments that encouraged empirical observations and experimentation. Since God was all-powerful, he could have made the natural world whichever way He wanted: he could have made the stones fly and the air sink to the bottom. There was no NECESSARY causes or purposes inherent in matter which could be logically deduced, as Aristotle had taught. The only way to really understand God’s purposes was to go out into the world and observe it.

(We will see examples of this attitude as we get into the sct. Rev).

The craftsman-scholar connection

This is the famous thesis of Edgar Zilsel which can be stated as follows:

The Zilsel Thesis can be stated in the following terms

Modern science arose in early modern Europe through the interaction of artisans and elite intellectuals and humanists in the universities. Both the artisans and the elite intellectuals were essential to the process. Craftsmen were not passive providers of raw material on which scientists worked, but rather, they were “real pioneers of empirical observation, experimentation and causal research.” Systematic, logical and mathematical thought, on the other hand was the province of “upper class learned people, for university scholars and humanists.” **It is only when the social barrier between the elite intellectual and the artisans broke down is that modern science could emerge.**

# Zilsel’s explanation of the transition between feudalism and early capitalism:

Modern science emerged in Europe when it was undergoing the transition from feudalism to early capitalism.

The science of the ancient Greeks that it had inherited had been produced under conditions of unfree labor and slavery: Ancient science and culture was the product of a small class of elite thinkers and philosophers who lived off the work of hands. [slavery in ancient Greek was considered a natural law: some were meant to rule and others obey.

Zilsel argued that no human society had ever under-gone such a radical change as the European society did when it moved from feudalism to early capitalism, starting around 15-16th centuries. The following five features of this transition from feudalism to capitalism were NECESSARY conditions for the rise of science:

1. Urbanization: In the feudal society of the Middle Ages, the castles of knights and the monasteries of churches were the centers of culture. In early capitalism, towns and cities became the centers of culture.
2. Technological advances: machines began to be used in production of goods and in wars. Technological advances in Zilsel’s words, “furthered causal thinking and weakened magical thinking.”
3. Individualism: In the medieval society, the individual was bound to the traditions of the group to which he belonged; while in early capitalism success depended upon individual enterprise. This individualism is a presupposition of scientific thinking, as the scientist also relies on his own eyes and senses.
4. Economic rationality: Feudal society was ruled by tradition and custom, while early capitalism proceeded rationally. It calculated and measured, introduced bookkeeping and used machines. The rise of ECONOMIC rationality furthered the development of rational scientific method. The emergence of the quantitative method, with is virtually unknown in medieval theories cannot be separated from the counting and calculating spirit of capitalistic economy. The classical mathematical tradition of Euclid, Archemides etc could be revived in the 16th century because the new society demanded calculation and measurement.
5. The rationalization of the state and the law: the loose state of feudalism and its traditional law was superseded by absolute monarchies with central laws.

# Zilsel on three classes or strata of intellectuals in 1300-1600

The above five were the general characteristics of the early capitalist societies which formed the NECESSARY conditions for the rise of science. But in order to understand the rise of science sociologically, Zilsel distinguishes THREE strata of intellectual activity: the university professors/scholars, the humanists, the workers.

1. **Universities:** theology and Aristotlian thinking predominated. This promoted a special kind of style of thinking which rationalizes “vague and contradictory mythological traditions”. Zilsel here cites the examples of “Brahmans in India, Buddhist theologians in Japan, Arabic and Catholic scholastics” These kind of scholars “indulge in subtle distinctions, enumeration and disputation [what I have been calling in this class as “commentaries upon commentaries…endlessly.”]. when these schoolmen looked at nature and other secular phenomena, they “ did not, as a rule, investigate cause and effect and physical law. They rather tried to explain the ends [purposes, desires] and meanings of phenomena.” According to Zilsel, “by the middle of the 16th century, the universities were hardly affected by the development of contemporary technologies and by humanism. Their spirit was medieval which resisted change.” Thus, as we have seen in earlier lectures, university trained medical doctors did not do any dissections themselves, but were happy to simply comment upon the work of surgeons and barbers.
2. **The Humanists:** the second strata of intellectuals were the non-university scholars – secretaries and officials of municipalities, princes and the churches. Many of these so-called Renaissance Humanists were dependent on the patronage of princes, noblemen and bankers (this included eminent scientists, e.g., Galileo, Kepler, Tycho): they received their living from these rich patrons with the understanding that they will make their patrons famous by their writings . They were the men of renaissance who looked back at the classical past and tried to revive the ancient Greek and Hellenic learning. These humanists were seeking to achieve the glory of the ancients: they tried to imitate the writing style of ancient Greek and Latin writers like Cicero and Plato (Here we can include Vesalius, who wrote in the style of ancients, even though he was challenging Galen.)

Humanists, like the university scholastics, neglected “causal research and physical laws and quantitative investigation. They were more interested in words than in things.

BOTH THESE CLASSES – UNIVERSITY PROFESSORS AND HUMANISTS – WERE VERY PROUD OF THEIR SOCIAL RANK AND. BOTH DISDAINED ORDINARY PEOPLE. THEY AVOIDED THE VERNACULAR AND WROTE IN LATIN. THEY WERE ATTACHED TO THE UPPER CLASSES, SHARING THE SOCIAL PREJUDICES OF THE NOBILITY AND THE RICH MERCHANTS. THUS THEY LOOKED DOWN UPON MANUAL LABOR AND CHOSE ONLY THOSE PROFESSIONS WHICH DID NOT REQUIRE WORKING WITH THE HANDS.

1. Craftsmen and Artisans: Let me quote directly from Zilsel:

“ beneath both the university scholars and the humanists, the artisans, the mariners, shipbuilders, carpenters, foundry-men and miners worked in silence on the advance of technology and modern society. They had invented the mariner’s compass and guns, they constructed paper mills, wire mills and stamping mills; they created blast furnaces and in the 16th century, introduced machines into mining. Having outgrown the guilds, and being stimulated to innovation by economic competition, **they were no doubt the real pioneers of empirical observations, experimentation and cause-and-effect research**. They were uneducated and often illiterate and that is why we don’t even know their names. “

**Rise of the “superior craftsmen”:**

**Over time, the working classes began to differentiate between “superior” artisans and craftsmen who needed more knowledge for their work.** These superior craftsmen and instrument-makers were already quite well-advanced in experimentation and measurement. They had developed quantitative rules of thumb which were the forerunners of experimentation and measurement. They had no use of “purposes” and occult qualities of nature. The verbosity (in Latin) of university scholars was of no use to them. Gradually they began to write books -- not in Latin but in their own mother tongues (Dutch, German, French, Italian and what have you ), not for the scholar, but for fellow craftsmen and merchants.

What caused the rise of the “superior craftsmen”?

The royal kingdoms, the princes and the nobles of Europe’s many small countries and city-states began to take an interest in the promotion of arts and technologies, especially for wars, buildings churches and cathedrals; creating public resources like roads, bridges canals etc. This meant that they started sponsoring artisans, engineers, architects.

This encouraged artisans of all kinds, but especially gunners, architects, gold-smiths (who also made clocks and other instruments) and alchemists to put down their knowledge in writing – so that they could seek the royal patronage. (before that , they used to keep their crafts’ knowledge a secret). In order to seek patronage and advertise their skills, they also started to make drawings of the buildings, machines etc. on paper. This encouraged the style of art called “perspective” in which a sketch in two dimensions gives the impression of depth. This also forced the artisans to draw to scale, which required mathematics.

Craftsmen-scholars thesis: These superior craftsmen had developed considerable theoretical knowledge in the fields of mechanics, acoustics, chemistry, anatomy by working with their hands. **But since they had not learned how to proceed systematically, their achievements formed a collection of isolated discoveries**. **These superior craftsmen were not scientists, but they were the immediate predecessors of science.**

**Before 1600, the craftsmen were separate from the scholars and the humanists: methodological training of the intellect was reserved for the scholars, experimentation and observation left for the craftsmen.**

Among these superior craftsmen were:

1. Artist-engineers made up a remarkable group in the 15th century. They not only paint pictures, but cast statues, build cathedrals, constructed lifting engines, canals and fortresses etc. They invented new pigments, constructed new measuring tools etc. The most well-known of these is Fillipo Brunelleschi (1377-1446) who is famous for developing the skill of building domes for churches and cathedrals.

But first these artist- engineers had to differentiate themselves from whitewashers, masons and stonecutters. Here let me cite the famous example of Leonardo da Vinci who is today celebrated as a supreme example of the Renaissance who was not only a great artist but also a great inventor and even a great anatomist whose sketches of the human body were used for medical education.

But in his own time, he was looked down upon by the elite as he lacked a classical education and was not literate in Latin: university scholars classified him as a manual laborer. He in turn scoffed at the latin speaking scholars as “puffed up and pompous, decked out and adorned not with their own labors but with those of others. “

Many of these artists-engineers wrote in vernacular for their colleagues. They were trained not in universities but as apprentices with other master artists: such well known artists as da Vinci, Botticelli and Michaelangelo started out as apprentices with goldsmiths. These artists would later develop the techniques of surveying and perspectivism, the art of representing three dimensional objects in two dimensions. In doing this, they developed the mathematics of linear perspective which, in da vinci words “ has to do with the function of the lines of sight, proving by measurement how much smaller is the second object than the first, and third from the second and so on until the limit of things is seen.” Initially mathematicians completely ignored this innovation but by the late 17th century, mathematicians were studying the work of artists. The artists who pioneered perspective, also developed instruments resembling the camera obsura that helped them capture the scene they were trying to paint. The invention of perspective by artists is

1. Makers of nautical and astronomical instruments: they made compasses, astrolabes, cross staffs, quadrants … (These are the craftsmen hired by astronomers like Tycho and Galileo.) Their measuring instruments are the forerunners of the modern physical apparatus. Many of these men were retired navigators and gunners.
2. Surveyors, navigators, map-makers.

These “mathematician craftsmen” practically revolutionized the surveying by supplanting traditional land-measuring procedures with a method of triangualation that required measuring angles and applying the principles of trigonometry. Indeed, the famous mapmaker Gerardus Mercator (1512-1594) – after whom the Mercator projections and maps are even still used –had established a workshop in Louvain (Belgium) which became renowned around the world for practical mathematics.

There was a great demand for practical mathematical skills developed by these people as technology and commerce were growing and there was a need for workers who understood the principles of surveying, navigation, gunnery and fortification.

To satisfy this market and to communicate their ideas to fellow craftsmen, the mathematician-artisans wrote books in vernacular and set themselves up as “professors of mathematics”. Mercator himself published an instruction book. Other books of that era bore names like Mathematical Jewell (John Balgrave, 1585, described how to make an astrolabe), *A Regiment for the Sea* (1571, William Bourne), A book of Quardant, Sector and Crosse-Staff (late1 500s by a “mathematical instrument maker” by the name of Edmund Gunter).

1. Surgeons-barbers. Many had contact with artists: We have already looked at the work of Ambrose Pare.
2. Makers of pianos, violins and other musical instruments.

Galileo’s father was in this group.