Lecture 6

The Medieval Synthesis and the Secularization of Human Knowledge: The Scientific Revolution, 1543-1642 (1)

Why then do we hesitate to grant [the Earth] the motion which accords naturally with its form, rather than attribute a movement to the entire universe whose limit we do not and cannot know? And why should we not admit, with regard to the daily rotation, that the appearance belongs to the heavens, but the reality is in the Earth?

---Copernicus, On the Revolutions of the Heavenly Bodies (1543)

I do not feel obliged to believe that that same God who has endowed us with senses, reason, and intellect has intended to forgo their use and by some other means to give us knowledge which we can obtain by them.

---Galileo, Letter to Grand Duchess Christina (1615)

Perhaps one of the most important, if not the greatest, development in the western intellectual tradition was the Scientific Revolution. The Scientific Revolution was nothing less than a revolution in the way the individual perceives the world. As such, this revolution was primarily an epistemological revolution -- it changed man's thought process. It was an intellectual revolution -- a revolution in human knowledge. Even more than Renaissance scholars who discovered man and Nature (see Lecture 4), the scientific revolutionaries attempted to understand and explain man and the natural world. Thinkers such as the Polish astronomer Nicholas Copernicus (1473-1543), the French philosopher René Descartes (1596-1650) and the British mathematician Isaac Newton (1642-1727) overturned the authority of the Middle Ages and the classical world. And by authority I am not referring specifically to that of the Church -- the demise of its authority was already well under way even before the Lutheran Reformation had begun. The authority I am speaking of is intellectual in nature and consisted of the triad of Aristotle (384-322), Ptolemy (c.90-168) and Galen (c.130-201). The revolutionaries of the new science had to escape their intellectual heritage. With this in mind, the revolution in science which emerged in the 16th and 17th centuries has appeared as a watershed in world history. The long term effects of both the Scientific Revolution and the modern acceptance and dependence upon science can be felt today in our daily lives. And notwithstanding some major calamity -- science and the scientific spirit will be around for centuries to come.
In 1948, the British historian Herbert Butterfield prepared a series of lectures to be delivered at the History of Science Committee at Cambridge. These lectures became the foundation for his book, *The Origins of Modern Science*. In the Preface to this work, Butterfield wrote that:

*The Revolution in science overturned the authority in not only of the middle ages but of the ancient world -- it ended not only in the eclipse of scholastic philosophy but in the destruction of Aristotelian physics.*

The key word here, I suppose, is authority. The Renaissance and Reformation also attacked the stranglehold of medieval authority but with quite a different purpose and with decidedly different results. However, Butterfield continues:

*The Scientific Revolution outshines everything since the rise of Christianity and reduces the Renaissance and Reformation to the rank of mere episodes, mere internal displacements within the system of medieval Christianity.*

Consider the period in which Butterfield makes this statement. It's 1948, just a few years after Hiroshima -- 78,000 men, women and children died within fifteen minutes of the dropping of the atomic bomb. This is what science has given us. And although I doubt whether Butterfield, civilized Englishman that he was, would have gloated over this fact of neat and efficient killing, the fact remains that this was science in action.

There are numerous questions we could ask ourselves about the Scientific Revolution: why it occurred? what forces produced it? why was it so revolutionary? why was it stronger in the Protestant North? But to my mind, before we can even begin to cope with these questions we must ask a much more basic question: **What is science?**

Science is no doubt with us today -- it surrounds our daily lives to such an extent that we now take it as a given. We expect science to be, to exist. Its effects and products touch the statesman and the soldier, the house husband and the grocer. Science has given us nylon, fluoride, latex paint as well as 747s, ever-faster microchips and PEZ. But science has also given us fluorocarbons, heroin, nuclear waste, dioxin and the atomic bomb. Science can be a mixed blessing -- with much that is good comes much that is clearly bad. But, what do we mean by science?

**Science is faith.** And the Gospel of that faith was written by Copernicus, Galileo, Newton, Darwin, Einstein and others. We are certainly not all scientists. I know I'm not a scientist. But yet, I'm sure that scientists are busy at work solving problems, the solution to which will help me in some way. **Perhaps scientists can improve our situation here on earth, just as the Gospels perhaps did almost two millennia ago. A scientist is an expert** and for some reason we have grown to trust experts. **The scientists, the technicians, the experts -- they must know the answers to our questions.**

We are surrounded by science whether we recognize it or not. Just about everything we see, touch, smell and hear, is a product of science. Furthermore, science has a language all its own, a
language which uses expressions like: rational, method, methodological, systematic, rules, laws, behavior, experts, technology and so on.

What I would like to suggest is that for the non-scientist, science is an idea. And this idea -- science -- gives us ways in which to think about and explain our world and ourselves. Science provides a world view, a way of making sense out of the apparently random and meaningless experience we witness throughout our lives.

The origins of this world view emerged full blown in the Scientific Revolution of the late 16th and 17th centuries. The Revolution itself was European -- it was cosmopolitan. Its short term effects were felt throughout the Continent and in England. And today, barely three or four centuries after the fact, there are few areas on the globe that remain untouched by modern science, whether for good or bad.

In the 16th and 17th centuries, scientists, theologians, philosophers and mathematicians were engaged in a vigorous debate over the natural world. Not so much man, but Nature. After all, the Renaissance had refined the dignity of man as perhaps distinct from the human depravity that the Church had preached. Nature -- the new focus was Nature. But why was this a subject for examination? Why had Nature become the new object of study? The reasons for this are complicated but for now I will suggest that answer lay with the Christian matrix. More specifically, the new focus on Nature was a direct result of the collapse of the Christian matrix, and this was the result of a combination of forces which produced intellectual change. To be brief, these forces were the Renaissance, Reformation, the Age of Exploration and the spirit of capitalism. The major obstacle faced by the scientific revolutionaries was one of knowledge -- it was a specifically epistemological question. If an older world view was to break down, the something would have to take its place. A new human identity was required -- it was essential to the changes in the intellectual climate. How could the world be known? Another way of putting this is to say that if the Renaissance had discovered man and Nature, then it was up to the scientific revolutionaries to verify their knowledge of man and Nature.

What did science mean to the scientific revolutionaries? One of the problems inherent in this question is that the revolutionaries rarely used the word science. Instead, they talked and wrote about natural philosophy or the philosophy of nature. Nature, to them, meant the natural world, that is, what was natural, what was not made by human hands. I would suggest that using the expression the philosophy of nature was really a hangover from the medieval world. In other words, questions of science were subsumed under the study of philosophy, and since medieval man called the phenomenal world Nature, then it was quite logical to refer to the study of Nature as the philosophy of Nature.

Above all, science meant astronomy and mathematics. These seemed to be the only two fields of study which embraced both laws and the explanation of those laws. Astronomy and mathematics have their own symbols -- they have their own language. This language, though difficult, is stronger than any other language because of its power to be understood by people who speak different languages. In other words, the language of science is universal. Whereas Charlemagne (742-814) had created a scholarly language -- we call it, medieval Latin --
the scientific revolutionaries created a language of science, and we call this language, mathematics. The legacy of all this to the modern world -- to our world -- was the scientific way of thinking -- it is a process of thought which is technical, mathematical, logical and precise. It's complicated too -- it's difficult for the non-specialist to understand. But perhaps not that difficult. Consider the following definition of man given by R. Buckminster Fuller, the father of the geodesic dome:

*Man is a self-balancing, 28-jointed adapter-base biped, and electro-chemical reduction plant, integral with the segregated stowages of special energy extracts in storage batteries, for subsequent activation of thousands of hydraulic and pneumatic pumps, with motors attached; 62,000 miles of capillaries, millions of warning signal, railroad and conveyor systems, crushers and cranes, and a universally distributed telephone system needing no service for seventy years if well managed, the whole extraordinary complex mechanism guided with exquisite precision from a turret in which are located telescopic and microscopic self-registering and recording range-finders, a spectroscope, etc.*

This is science gone absolutely crazy. Of course, such a definition of man ignores his nature -- his emotions, dreams, joy, sadness, successes and failures. In fact, Fuller seemed to ignore everything that made the individual fully human. It is a mechanical explanation of man -- man as machine. It is also an explanation of man that would not have been possible had it not been for this intellectual development we call the Scientific Revolution. The irony, however, is that if somehow we could have gotten Galileo and Fuller together over lunch, Galileo would have perhaps found Fuller positively mad.

Before we talk about the scientific revolutionaries, the implications of their work and their world view, it is necessary to examine the medieval world view. It was, after all, the world view of medieval man that the scientific revolutionaries made the deliberate attempt to overthrow. The medieval world view -- the linchpin of the Christian matrix -- was fashioned from the ideas of four men. Two of them were from the ancient world -- Aristotle and Ptolemy. And the other two were of the medieval world -- Aquinas and Dante.

According to the medieval world view, Nature was conceived to be kept going from moment to moment by a miracle which was always new and forever renewed. It was God who ordered the universe through these miracles. This entire scheme depended not only upon God, but upon the individual's absolute and unwavering faith in God. If God pronounced it to be so, then it must be so. But after 1350, let's say, by the time of Petrarch, some men became more interested in the form of the miracle. Knowing that the cosmos was of divine origin and moved according to the will of God, some men embraced that Faustian spirit that wanted to know more. It was not enough to simply accept the existence of miracles -- the miracles now had to be explained. These men wanted to know what order, to what hierarchy the miracle conformed. And this brings us to the medieval view of cosmological order. According to the intellectual tradition stretching from Aristotle to Dante, all things in nature -- all phenomena -- are composed of four fundamental elements. These elements were air, fire, earth and water. These elements were believed to follow certain laws -- they were to follow their ideal nature. So, since they are heavy and coarse, water and earth move downward. Likewise, since they are light and airy, air and fire move upward.
Each of the four elements is constantly striving to reach its natural center. The striving of all these elements is what kept the cosmos going. In this scheme of things, the elements of air and fire predominated and together they composed a fifth element, more pure than the rest, which the ancients called "the aether." And since the heavenly bodies are "up there," they must be composed of "the aether."

Which brings me to relate a brief story. In 1666, and with the city of London burning down, Isaac Newton left his study at Cambridge and made his way to his mother's home at Woolsthorpe in Lincolnshire. It was here, in his mother's garden, that the great Newton was struck by an idea - the idea that the force which held the planets in their orbit was the same force which caused an apple to strike him in the head. Such an idea -- we of course know it today as gravity -- would have been absolutely unintelligible even to an advanced medieval thinker. This is so for two reasons. First, medieval man did not see the movement of the heavenly bodies from the standpoint of the mechanics of motion. The heavenly bodies, after all, were composed entirely of aether. Theirs was an organic, living world view rather than our now more familiar mechanical conception. Second, and perhaps of even more importance, medieval man could not understand that the planets or the stars or comets were made of the same stuff as an apple -- matter.

When it came to conceptualizing the universe, the medieval world borrowed its knowledge from the Egyptian geographer and astronomer Claudius Ptolemy (c.90-168). The Ptolemaic System put the stars on a fixed sphere around the earth. At the center was an object about which nine concentric sphere were situated. This object was the earth. Beyond the earth, its position fixed, were the Moon, Sun, Mercury, Venus, Mars, Jupiter, Saturn and then the stars, and finally, the Prime Mover, the First Cause, God. The motions of the planets were complicated. Ptolemy said the planets moved in epicycles. The concept of epicycles was used by Ptolemy to explain why planets seemed to exhibit what is now known as retrograde motion, that is, the tendency for planets to move in one direction, then stop, change directions and then continue their original movement. Ptolemy's system was accepted during the Middle Ages but over time it became awkward. As improvements were made in the skills of observation, more and more epicycles were called for to explain the movement of heavenly bodies. A simple, regular, ordered and hierarchical system had, over time, become very complicated. Criticism of the Ptolemaic system began in the mid-16th century. The system which eventually overthrew that of Ptolemy was not based on criticism alone. Instead, another system took its place -- and that system came with the emergence of the New Science.

So monumental were his achievements in cosmology, the Scientific Revolution could almost have been called the Copernican Revolution. Born in Poland in 1473, it was the humble astronomer Nicholas Copernicus who challenged the geocentrism of Ptolemy with his own heliocentric universe. Ptolemy would never recover -- neither would the Christian matrix. Copernicus studied mathematics at Cracow and managed to obtain a law degree from Bologna as
well. In 1500 he was in Rome where he witnessed a lunar eclipse. The following year he studied medicine at Padua and in 1505 he left Italy for Prussia. By 1512 he was settled in Prussia where he not only observed the movement of the heavenly bodies but also worked in various capacities as a bailiff, military governor, judge, tax collector, physician and reformer of the coinage. He was an untypical man, an exceptional man, like one of his contemporaries Sir Thomas More, a Renaissance man.

As well all know, it was Copernicus who determined that the sun was at the center of the cosmos and that the earth moved. Such an opinion alarmed his contemporaries who could not explain that if the earth were spinning then why didn't an arrow shot into the air fly off the face of the earth -- remember, this is well before the idea of gravity had been discovered by Newton. The Copernican system offended the medieval sense that the universe was an affair between God and man. Copernicus knew it too. The ultimate authority, of course, was the Holy Writ. That his contemporaries would be alarmed by the heliocentric theory bothered Copernicus. So, he decided to publish his findings in 1543, the year of his death. It was in that year that Copernicus published his magnum opus, *De revolutionibus orbium coelestium* (On the Revolutions of the Heavenly Bodies). Aware that he could not persuade the traditional thinking of the time, Copernicus made a specific appeal to mathematicians. It was, he thought, only the mathematician who could understand and appreciate the order and essential simplicity of his system. In the DEDICATION to this most revolutionary of scientific treatises, Copernicus wrote:

*mathematics is written for mathematicians, to whom these my labors, if I am not mistaken, will appear to contribute something.*

Copernicus never expected that his findings would appeal to the non-specialist. But in 1572 something happened. A new star appeared in the constellation of Cassiopeia. The new star was observed by a Danish astronomer by the name of Tycho Brahe (1546-1601). The star was brighter than any other star for more than two years -- contemporary accounts tell us that the star was so bright that it could be seen in daylight. And in 1600, another star appeared. This star was observed by Johannes Kepler (1571-1630). The heavens seemed to be in flux. Such occurrences made lasting impressions on all men, whether scientist or not. After all, this was an age in which men believed their fate to be written in the stars and now those stars were changing. What Brahe and Kepler had seen were super-novas, the explosions of old stars.
Kepler, even more than Copernicus, was literally carried away by the strange relationship between numbers and the properties of the natural world. In his books, *Mysterium Cosmographicum* (*The Mysterious Universe*, 1596) and *Harmonice Mundi* (*The Harmonious World*, 1619) one theme is presented repeatedly: "Nature loves simplicity." From his friend Brahe, Kepler learned that it was necessary to take more accurate measurements while observing the movement of the heavenly bodies. In the end, Kepler determined the three laws of planetary motion, which he published between 1609 and 1619. (1) planets move in elliptical orbits. (2) explained the varying speed of the planets and so, retrograde motion, (3) relates the movement of one planet to all the others. With the discovery of these three laws within the framework of the heliocentric universe, the paths of the planets were mapped forever. All that remained would be to see these three laws as part of a single unity -- a single law which held each planet in its orbit about the sun. This of course, would have to wait another seventy years -- this single law would have to wait for the genius of Isaac Newton. But what was needed before Newton could go to work was a more practical and elaborate understanding of the mechanics of motion.

And this practical understanding of mechanics would be provided by an Italian astronomer and mathematician by the name of Galileo Galilei. Born at Pisa in 1564, Galileo studied medicine and mathematics and became a professor at Pisa in the late 1580s. But because the largely Aristotelian faculty was hostile to him, Galileo decided to move on to Florence. Eventually he settled at Padua and between 1592 and 1610 his mathematics lectures at the university attracted students from across the Continent.

The key to all of Galileo's discoveries was the accurate measurement of time. Accurate measurement of time was essential if the mechanics of motion were to be explained. By 1600, there were no accurate clocks or time keeping devices. There were clocks, of course, but none of them were at all precise. Medieval clocks were convenient for dividing the day but not for keeping precise time. Galileo was fascinated with time. As the story goes, Galileo was attending a religious service at Pisa in 1583. His thoughts began to wander and as he gazed about he noticed the swinging motion of a lamp that hung from the ceiling. It was then that Galileo was struck by the uniform motion of the pendulum. The pendulum, if kept swinging at a constant rate, keeps near perfect time. Galileo experimented with various sorts of motions and falling bodies. This, after all, was what helped him determine the mechanics of motion. His observations of falling bodies at the Leaning Tower of Pisa are only the most well known of his experiments. He rolled balls of varying size and weight down slopes with varying angles of incline. He showed that an object thrown into the air falls to the earth along a parabola. What he ended up doing was casting doubt on Aristotelian mechanics -- he challenged the monopoly on scientific education enjoyed by university clerics who had, so he thought, learned nothing since their earliest encounter with Aristotle.

Around 1609 Galileo had news of a development from Holland -- a lens grinder had taken two lenses and placed them at opposite ends of a metal tube. A rudimentary telescope was the result. Galileo made his own telescope as well as a compound microscope. Galileo directed all of his attention to the heavens. He was the first man to see craters on the moon, sun spots and the rings of Saturn. He also observed the phases of Venus. He determined that the Earth's moon was not a source of light but rather of reflected light. He saw the moons of Jupiter. And of course, Galileo
was also a Copernican: "Sol est centrum mundi, est omnio immobile motu locali," ("The sun is the center of the universe and the earth moves.")

In 1611, Galileo packed his brass telescope in his bag and decided to go to Rome. The previous year, Galileo had reported his findings in his book, THE STARRY MESSENGER. Criticism of Galileo's observations began immediately. The authorities at Rome would not even look through his telescope. Why not? They had absolute faith in Aristotle. Not only that, if you think about it, the telescope reveals the existence of things which are not really there. Look at the heavenly body called Saturn with the naked eye. Do you see its rings? Of course not. In Galileo's day, seeing something that could not be seen with the naked eye was the same thing seeing apparitions or hearing voices -- it was the work of the Devil! The religious authorities at Rome were uneasy with the New Science. Copernicus, Kepler and Galileo seemed to be turning the world upside down. The sun was the center of the cosmos, the earth moved and the sky seemed to hold hidden visions. In effect, the Scientific Revolution had created an invisible world behind the visible world and those men of an older generation, weaned on Aristotle and Aquinas were fearful of it.

On April 12, 1615, Cardinal Bellarmine wrote his famous LETTER TO FOSCARINI, a letter which expressed his displeasure with Copernican theory. The following year, Galileo was summoned to Rome and ordered to desist teaching Copernican theory. He was, however, free to think about Copernican theory, but he could not teach it or write about it. Galileo agreed to this condition but still maintained that his mechanical philosophy described the natural world better than any other alternative explanation. He was confident, extremely confident, that his position was the correct one. So confident was Galileo that in 1632 he imagined that the decree regarding his public advocacy of Copernican theory could be overturned. He began to criticize the clergy who would preach the damnability and heresy of the new doctrine from their very pulpits with unwanted confidence, thus doing impious and inconsiderate injury not only to that doctrine and its followers but to all mathematics and mathematicians in general.

The new science, so though Galileo correctly, was unsuited to pulpit discussion. In fact, Galileo was more than aware of this necessity and in the defense of the new science, we can see the first stage of a century long struggle between faith and reason.

The new science was also unfit for public discussion. On the one hand, as a practical man with an eye toward the applicability of science, Galileo knew that the new science could improve the human condition. On the other hand, however, he argued that it was necessary to not allow the public too much knowledge regarding the motions of the heavenly bodies -- at the very least, the public mind ought to be enlightened slowly and cautiously:

The shallow minds of the common people must be protected from the truth about the universe lest they should become confused and obstinate in yielding assent to the principle articles that are absolutely matters of faith.

In Galileo's mind, the new science was a body of knowledge intended for the learned elite. It was
not intended for public consumption. Furthermore, Galileo argued time and again, the new science did not contradict the deeper meanings of the Holy Scriptures. The wise man should seek the true sense of the Scriptures, the true meaning. But, in matters of physical problems, we ought not begin from the authority of Scriptural passages but from sense experience and necessary demonstrations: in a word, natural philosophy. Aristotle had not observed enough, nor as freely as Church authorities believed and so Galileo and the rest of his fellow revolutionaries went beyond The Philosopher -- they had done a much better job of using their senses. By arguing that man must look beyond the literal meaning of the Scriptures, Galileo unwisely put himself in disagreement with Council of Trent. In 1546, the Council prohibited "any attempt to twist the sense of Holy Scripture against the meaning which has been and is being held by our Holy Mother Church." The Council, of course, was clearly reacting to the onslaught of the Lutheran Reformation. The medieval synthesis had been assaulted on several fronts but in one last ditch effort, Rome built its last defense -- Galileo was the fall guy!

In 1623, Galileo's friend and admirer Maffeo Barberini was elected Pope Urban VIII. An intelligent but vain man, Barberini had much in common with Galileo -- both men considered themselves above the common man. Galileo enjoyed six audiences with Baberini and was rewarded with lavish gifts from him. Galileo reasoned that the time was now right to publish a new defense of Copernican theory. His confidence at an all time high, he spent four years composing the new Copernican manifesto. His Dialogue Concerning the Two Chief World Systems, Ptolemaic and Copernican, was cleared by Church censors, one of whom was Galileo's former student, and was published at Florence in 1632. As the title suggests, Galileo grounded his manifesto in the form of a dialogue rather than a treatise. The dialogue, Galileo reasoned, was a device through which an argument for Copernican theory could be made without violating the papal decree of 1616. Two of the conversants -- Salviati and Sagredo -- are sympathetic to Copernican theory. Simplicio, the third participant, represents Aristotle and the Scholastics and is presented as fool. Galileo's enemies were quick to inform the Pope that the official cosmology of the Roman Catholic Church had been put in the mouth of Simplicio. The Pope ordered an investigation and so in August 1632, less than six months after it had appeared, the Inquisition banned further sales of the book. Galileo's book was placed on the Index of Forbidden Books and there it remained until 1757.

Galileo was ordered to appear before the Inquisition at Rome. He awaited intervention by the Pope, his former friend, but it never came. He also believed, quite innocently, that he could show that Copernicanism was not in any direct opposition to Church dogma, However, as Galileo found out, what was at issue was not so much heliocentricity but authority. Galileo quickly realized what was at stake. The now seventy year old Galileo was interrogated relentlessly and threatened with torture. The Church had a strong defense -- it was clear that Galileo had violated the prohibition placed upon him in 1616. He could believe Copernican theory but not publicly defend it. To prove their position, the Church produced the forged minutes of Galileo's meeting with Cardinal Bellarmine in 1616. Unfortunately for Galileo, by 1632, Bellarmine was dead. The document produced by the Church was clearly forged. It acknowledged that Galileo could not hold, teach or defend Copernican theory in any way. This was a much stronger prohibition than Galileo could recollect. (See the Galileo Trial Documents) Without a defense of any kind, Galileo took his only reasonable option and on June 22, 1633, he recited the required abjuration
on his knees:

_Wishing to remove from the minds of your Eminences and of every true Christian this vehement suspicion justly cast upon me, with sincere heart and unfeigned faith I do abjure, damn, and detest the said errors and heresies, and generally each and every other error, heresy and sect contrary to the Holy Church; and I do swear for the future that I shall never again speak or assert, orally or in writing, such things as might bring me under similar suspicion._

The trial at an end, the abjuration made public, _the broken Galileo spent his remaining eight years under house arrest at his villa outside Florence_. It was at this time that he wrote perhaps his finest book, the _Dialogues Concerning Two New Sciences_, a study of motion and inertia. His daughter, Sister Marie Celeste, whom he had sent to a convent against her wishes twenty-three years earlier, stayed with him to the end. Every day she said the seven Psalms of penitence ordered by the Holy Office as part of his sentence.

Galileo continued to gaze at the stars through his telescope until 1637, when his sight finally failed him. "This universe that I have extended one thousand times," he wrote, "has now shrunk to the narrow confines of my own body." The trial and condemnation of Galileo marked the climax of the first wave of the Scientific Revolution. He had helped to unlock some of the mysteries of the cosmos for his fellow man. However, his trial also signified something else. The weight of papal authority which had brought Galileo to his knees also succeeded in halting the growth of the new science in Italy. It is no accident then, that following Galileo's death in 1642 that the greatest advances in science would come from outside Italy in countries like England, Holland and Germany. These were, after all, Protestant countries with a tradition of protest and toleration. But 1642 also signifies something else for it was in that year that the man most responsible for producing modern science was born. That man was Isaac Newton.