9 Intellectual Consequences of the 17th Century Scientific Revolution

9.1 Recap of Cosmological Developments

Greek cosmology
- We began with the invention of the idea of a scientific theory by the pre-Socratic philosophers.
- They attempted to find underlying and unchanging principles responsible for the constantly-changing phenomena of the everyday natural world.
- The Greeks developed a cosmological theory with the Earth at the center and the planets, Sun, & Moon embedded in spheres rotating around the Earth.
- The motions in the heavens were understood in terms of Aristotle's theory of motion.
- This model was given further refinements in the Greek world over the next 600 years, to correspond more closely to observations, and culminating in the Ptolemaic construction with epicycles, deferents, eccentrics, etc.

Medieval cosmology
- The Ptolemaic model got to Europe in the Middle Ages, largely via the Islamic civilization.
- It was taken over, along with Aristotle's philosophy and integrated by the Scholastics into Christian theology.
- The world-view that emerged was one that was highly structured and hierarchical, with Earth and the entire cosmos integrated with Christian ideas of hell and heaven.
- All the order in the Universe derived from God, and society was organized under monarchs whose rule was ordained by God.
- The Great Chain of Being was one example of this hierarchical order.

Renaissance cosmology
- Copernicus introduced the idea that the planets, including the Earth, orbit round the Sun, but he could not get rid of the epicyclic and eccentric motion.
- This model produced predictions of positions of planets and other astronomical events with similar accuracy to Ptolemy's model.
- It was no more accurate but easier to calculate with.
- (Tycho Brahe produced a composite model with all the planets going round the Sun, but the Sun going round the Earth.)
- These models were not generally considered to be pictures of reality—that remained the Ptolemaic model—partly because there was way to understand such motion in the heavens.

17th Century
- Galileo used the power of telescopic observations to show there are new astronomical phenomena that are quite incompatible with the Ptolemaic model.
- Galileo also argued for a new approach to doing science (natural philosophy).
- We have the Book of Nature, which God has given us, and we must use our senses and our reason to discover the mysteries of how it works.
- He also argued that the language of Nature is mathematics, and our descriptions of how Nature operates must be in terms of mathematics.
17th Century 2

- Kepler thoroughly analyzed Tycho's very accurate observational data—especially that on the positions of Mars—and discovered three laws of planetary motion:
  - Planets orbit the Sun in ellipses, with the Sun at one focus of the ellipse.
  - Planets speed up and slow down in their orbits so the line from Sun to planet sweeps out equal areas in equal times.
  - $\text{(Period)}^2 \propto (\text{major axis of ellipse})^3$.
- This is the beginning of the end not only for Ptolemaic cosmology, but also the medieval world-view with all its attendant understanding of the place of Man in the created world.
- There is now, however, the problem that there is no theory of motion to explain why the planets move in these ways.

17th Century 3

- The culmination of these and other developments that emerged during the 17th C was Newton's *Principia*.
- Newton produced a dynamics that applied equally to objects on Earth and in the heavens.
- He also proposed a theory of universal gravitation, which also applied uniformly to every object in the Universe.
- Using these Newton could derive purely mathematically Kepler's laws for the planets, and he could also account for the orbits of planetary moons, comets, tides, equatorial bulges, and measure the masses of the planets.
- In summary, Newton seemed to have developed a theory which could quantitatively describe the entire “system of the world,” i.e. a new cosmology.

The Scientific Revolution

- The 17th C saw the emergence of a new theory of motion and gravity, the confirmation of the helio-centric cosmology (and therefore the demise of the Ptolemaic model).
- But this period also ushered in a new way to find knowledge: it marked the end of the reliance on authority (e.g. Aristotle's concepts and principles) as the fount of wisdom and knowledge.
- There was a new emphasis on looking at every subject from a fresh point of view, and using reason to search for new universal principles, following the paradigm Newton had provided.
- For these reasons this period is often called the 17th Century Scientific Revolution.

9.2 The Scientific Revolution and the Enlightenment

- The 17th C Scientific Revolution gave birth to a larger intellectual revolution called The Enlightenment.
- Enlightenment thinkers were impressed by the results of the Scientific Revolution, viz.,
  - there are natural laws in the universe, and
  - they can be apprehended by human reason.
- Following the paradigm of the Scientific Revolution the program was to use reason to find natural laws in other fields in a similar way to what Newton (and others) had done in science.
- One hallmark of the Enlightenment was rejection of authorities of the past, and Aristotle in particular, as well as the authorities of the present—e.g. the Church and he Monarchy.

Enlightenment 2

- This was replaced with emphasis on reason and inductive empiricism (generalizing from results of experiments and observations), and a separation of religious knowledge from scientific knowledge.
- Examples of Enlightenment thinkers include: John Locke, Thomas Paine, Adam Smith, David Hume, and the French philosophes Rousseau, Voltaire, Diderot, and d'Alembert.
- In the universities of the early 18th C Aristotelian scholastic philosophy and methods still held sway.
- However the new philosophy captured the interest of a growing reading and thinking public, and new learned societies, journals, as well as salons and coffee-houses became centers of discussion of new ideas and experiments.
Enlightenment 3

- Accompanying this interest in the new philosophy was an optimism about progress and discussion of applications of the new ideas for the betterment of mankind.
- The French Encyclopédie project is a paradigmatic example of the mentality of the Enlightenment.
- The 17th C Scientific Revolution thus ultimately gave birth to a larger intellectual revolution which formed the modern mentality.
- We are heirs of the 17th C Scientific Revolution, not only in the scientific enterprise, but in the categories and methods with which we apprehend reality and find truth.

9.3 Some examples of searches for natural laws

In Politics: John Locke (1632-1704)

John Locke

- English physician, born of Puritan parents.
- Friend of Isaac Newton & member of the Royal Society.
- Became personal physician to Lord Shaftesbury, who was founder of the Whig Party (reformers opposed to the Tories) and was Lord Chancellor for a period.
- He wrote the two Treatises on Civil Government to defend the Glorious Revolution (1688), which deposed the Catholic monarch James II, replacing him with William & Mary of Orange.
- William & Mary also accepted the Bill of Rights, which ended absolute monarchy in Great Britain and replaced it with a constitutional monarchy.
- His other great work is the Essay Concerning Human Understanding.

Excerpts from the 2nd Treatise

To understand political power right, and derive it from its original, we must consider, what state all men are naturally in, and that is, a state of perfect freedom to order their actions, and dispose of their possessions and persons, as they think fit, within the bounds of the law of nature, without asking leave, or depending upon the will of any other man.

The state of nature has a law of nature to govern it, which obliges every one: and reason, which is that law, teaches all mankind, who will but consult it, that being all equal and independent, no one ought to harm another in his life, health, liberty, or possessions....

If man in the state of nature be so free, as has been said; if he be absolute lord of his own person and possessions, equal to the greatest, and subject to no body, why will he part with his freedom?

Why will he give up this empire, and subject himself to the dominion and controul of any other power? To which it is obvious to answer, that though in the state of nature he hath such a right, yet the enjoyment of it is very uncertain, and constantly exposed to the invasion of others....

The great and chief end, therefore, of men's uniting into commonwealths, and putting themselves under government, is the preservation of their property.

Yet it being only with an intention in every one the better to preserve himself, his liberty and property; (for no rational creature can be supposed to change his condition with an intention to be worse) the power of the society, or legislative constituted by them, can never be supposed to extend farther, than the common good; but is obliged to secure every one's property, by providing against those three defects above mentioned, that made the state of nature so unsafe and uneasy.
John Locke & politics

- In his Second Treatise on Civil Government (1689) Locke invokes the idea of natural law in society.
  - There is a natural law in politics that all people have certain natural rights of life, liberty, and property.
  - There is also a natural law not to harm others.
  - But there are some people who disregard natural law, and steal, enslave, or kill others.
  - People therefore band together into societies or nations to protect themselves.
- The conclusion: governments exist and have authority only because these were given to them by the people governed.
- A corollary is that the purpose of government is to give people as much individual liberty as possible.

In economics: Adam Smith (1723-1790)

Adam Smith

- Born in Scotland, just north of Edinburgh.
- Attended Universities of Glasgow & Oxford (wrote about the poor standard of English universities compared with Scottish universities).
- Began giving public lectures in Edinburgh.
- Became Professor of Moral Philosophy at Univ of Glasgow in 1752.
- Became tutor to the young Duke of Buccleuch in 1763, and traveled with him to France, meeting a number of the philosophes.
- On returning to Scotland he spent the next 10 years writing The Wealth of Nations.

Context to the Wealth of Nations

- The wealth of a nation was thought to be the amount of gold and silver owned.
- National wealth was achieved by a favorable balance of trade.
- Therefore governments strictly controlled trade (a form of capitalism called “mercantilism”).
- This is obviously an unstable situation, and led to pursuit of colonies by the European nations as both a source of raw material and a new market for manufactured goods.
- A group of the French philosophes argued that raw materials, rather than gold, constituted the wealth of a nation.
- Smith sought to find a natural law of balance that would insure an adequate supply of goods, fair prices for them, and fair wages to produce them.

Excerpts

It is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own interest. We address ourselves, not to their humanity but to their self-love, and never talk to them of our own necessities but of their advantages.

There is in every society or neighbourhood an ordinary or average rate both of wages and profit in every different employment of labour and stock. This rate is naturally regulated, as I shall show hereafter, partly by the general circumstances of the society, their riches or poverty, their advancing, stationary, or declining condition; and partly by the particular nature of each employment.

The Wealth of Nations

- In his Inquiry into the Nature and Causes of the Wealth of Nations (1776) Smith enunciated several natural laws:
  - Labor (rather than gold or silver) is the source of wealth in a nation.
  - All people are acquisitive.
  - There should be free access to raw materials, labor, and markets.
  - Each person has unique natural skills & abilities which make him or her best-suited to a particular type of work.
- Given these principles there is a natural law of supply and demand that will determine the correct supply of goods, fair prices, and fair wages.
Thomas Robert Malthus
(1766-1834)

- Born to a prosperous family in England.
- Studied many subjects but especially mathematics at Cambridge, was ordained and became a country parson.
- Published *An Essay on the Principle of Population* in 1798, chiefly in response to some of the ideas in circulation among the French philosophes.
- In 1805 he became the first professor of political economy in the East India College.
- Malthus’ ideas on population were widely influential in politics (e.g. the “Poor Laws,” economics, biology (Darwin), and he is considered the founder of the science of demography.
- Elected a Fellow of the Royal Society in 1818.

**Excerpts**

It is an acknowledged truth in philosophy that a just theory will always be confirmed by experiment.

I think I may fairly make two postulata. First, That food is necessary to the existence of man. Secondly, That the passion between the sexes is necessary, and will remain nearly in its present state.

These two laws ever since we have had any knowledge of mankind, appear to have been fixed laws of our nature; and, as we have not hitherto seen any alteration in them, we have no right to conclude that they will ever cease to be what they now are.

**Excerpts 2**

Assuming then my postulata as granted, I say, that the power of population is indefinitely greater than the power in the earth to produce subsistence for man.

Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio. A slight acquaintance with numbers will shew the immensity of the first power in comparison of the second.

This implies a strong and constantly operating check on population from the difficulty of subsistence. This difficulty must fall somewhere and must necessarily be severely felt by a large portion of mankind.

**Malthus on population**

- In the Essay on Population, Malthus argues there are several natural laws regarding population:
  - Population is limited by the food supply.
  - Population, if unchecked, increases at a geometric rate (e.g. 1, 2, 4, 8, 16, etc.).
  - However food supply cannot be grown at more than an arithmetic rate (e.g. 1, 2, 3, 4, 5, etc.).
  - When population begins to exceed food productivity, the effects fall disproportionately on the poor.
- The conclusion: since production of food cannot keep up with growth in population, it is imperative to find ways to control population growth.

**The French Encyclopedists**

- Circa 1745 the French publisher Le Breton conceived the idea of publishing a French translation of the English Chambers’ Cyclopaedia.
- In 1747 he hired Denis Diderot and Jean le Rond d’Alembert to co-edit a new Encyclopedie.
- It was published over the period 1751-1766, in 28 volumes, with illustrations and index not completed until ca. 1780.
The *Encyclopedie*

- Diderot & d’Alembert developed a vision for the new work to embody the ideas of the Enlightenment, destroying old superstitions, exhibiting the new ways of thinking, and providing access to the new knowledge that was forthcoming.
- There was also a strong bias toward application of the new knowledge to technology and practical skills.
- It incurred the wrath of the Church (it criticized Catholic dogma but wrote approvingly of the Protestant reformers) and was officially banned and closed down in 1759.
- But it was hugely popular, enjoyed a large print run, had several major supporters in high positions, and the authorities turned a blind eye to its continued development.

Another political example

- There is another special connection we in the U.S.A. have with the intellectual consequences of the 17th C Scientific Revolution. Consider:
  - “We hold these truths to be self-evident, that all men are created equal, and that they are endowed by their Creator with certain unalienable rights; that among these are life, liberty, and the pursuit of happiness. That to secure these rights, Governments are instituted among Men...”
- Thomas Jefferson and the other authors of this Declaration adopted the ideas of natural law in politics from John Locke (& others) as the justification for the American Revolution and the theoretical basis for our system of government.

...and also in France

- In 1789 the Declaration of the Rights of Man and Citizen was issued by the French National Assembly.
  - “The representatives of the French people...have resolved to set forth in a solemn declaration the natural, inalienable, and sacred rights of man...”
  - 1) Men are born and remain free and equal in rights; social distinction may be based only upon general usefulness.
  - 2) The aim of every political association is the preservation of the natural and inalienable rights of man; these rights are liberty, property, security, and resistance to oppression.
  - 3) The source of all sovereignty resides essentially in the nation; no group, no individual may exercise authority not emanating expressly therefrom.

In summary

- In the modern world we can find many intellectual consequences of the 17th C Scientific Revolution.
- The U.S.A. was founded on the political ideas of natural law which emerged in the thinking of Locke, Rousseau, and others (classic liberalism).
- The Laissez-faire capitalism of Adam Smith, which many Americans regard as the fundamental natural law of economics.
- It is the tacit assumption of modern life that there are universal natural principles which govern everyday life.
- It is another tacit assumption that the only certainty in knowledge comes from the empirical scientific method.
- A materialist, reductionist understanding of reality--the common assumption in the western world--is derived from these ideas.

Conclusion

- The underlying theme of these lectures is that
  - **IDEAS MATTER**
- Even the ideas of science and cosmology inhabit a larger world than science itself!
- I hope the lectures have convinced you that struggles over two millennia to understand how the stars and Moon and planets go around the sky stimulated new ways of thinking in completely different areas of human experience.
- As you reflect on what we have discussed, I hope you can begin to see how the modern mentality has been shaped by the intellectual implications of the 17th C Scientific Revolution, which in turn came out of two millennia of struggles to understand the large-scale Universe.