

The Creation of the Scientific Worldview

MWF, 11:00 – 11:50

Fall Semester

Roger Turner

History and Sociology of Science

University of Pennsylvania

Course Description:

The modern world has been shaped and reshaped by science. Our current explanations for some phenomena are nothing like the explanations of just 20 years ago; other explanations have been consistent for 400 years or more. This course traces the history of Europe (primarily) to see how knowledge about the natural world has enabled global agonies and ecstasies of the past 2500 years. It will introduce some of the most beautiful, puzzling and powerful ideas ever imagined. Lecture and section format.

Course Goals:

This course should help you assemble a “big picture” of the history of the modern world. It uses science—knowledge about the natural world—as a theme to guide our exploration of the development of “western civilization.” Along the way, we will explore some of the politics, art, music and economics that have defined western societies. I hope to stimulate you to think broadly, about interconnections between ideas and practice, between knowledge and power, and about how science has developed.

Course Format:

I will lecture on Mondays and Wednesdays. Most Fridays will have discussion sections led by the teaching assistants.

Assignments:

Most weeks, there will be a short (1-2 page) writing assignment, due Wednesday. There will also be a month-long assignment involving observation of the moon. This will be due on October 7th. I will hand out more instructions on a separate sheet.

Exams:

There will be two one-hour exams. The first will be October 19th, covering the first half of the course. The second exam will be on the day of scheduled classes, December 9th. There is no cumulative final. Both exams will give you a chance to synthesize information, demonstrating what you’ve learned and how it fits together. Facts are important, names and dates are the stuff of history; the ability to memorize is a high-school skill, however. The exams encourage you to synthesize the facts you’ve learned into broader stories about the role and development of science across time.

Instructor and Office Hours

I look forward to meeting you. Please come see me during my office hours, Tuesdays 9-11am. I can be reached by Email (rogert@sas.upenn.edu) as well.

Schedule:

Unit 1: The Origins of Modern Knowledge-----

September 7 (Wed): Introduction: What is Science, and When Did It Begin?
September 9 (Fr): Ancient Legacies: The Greco-Roman World

September 12: Lost and Found: The Medieval World
September 14: Scholars and Craftsmen: The Renaissance (**Weekly Paper #1 due**)
September 16: Section

September 19: Searching for the Ancient, Finding the New: European Exploration in the
15th and 16th Centuries
September 21: The Circulation of Knowledge (**Weekly Paper #2 due**)
September 23: Section

September 26: Circular Reasoning: The Copernican Revolution
September 28 The New Cosmos: Tycho and Kepler (**Weekly Paper #3 due**)
September 30: Section

Unit 2: Knowing and Believing-----

October 3: Revolutionary Politics: The Crime of Galileo
October 5: Living for the Truth: Science in the Catholic Church
October 7: “New Methods for the Truth: Bacon and Descartes” Lecture (No Section)
Telescope Assignment Due

October 10: Experimenting and Observing: The Royal Society
October 12: Newton’s World
October 14: Section

October 15th: Fall Break (No Class)

October 19 (Wed) **Midterm**
October 21 (Fr) No Section; Have fun with your family

October 24: Enlightenment: The Mechanical Spirit
October 26: The Order of Things (**Weekly Paper Due**)
October 28: Section

October 31: The Tipping Point: French Revolution
November 2: Romantic Science (**Need a Weekly Paper Due**)
November 4: Section

November 7: Digging and The Meanings of Fossils
November 9: Darwin: The Evolution of Evolution (**Weekly Paper Due**)
November 11: Section

Unit 3: Knowledge and Power-----

November 14: The Century of Progress?

November 16: Cells and Germs: Rise of Scientific Medicine (**Weekly Paper Due**)

November 18: Section

November 21: Matter and Energy: Theory and Practice

November 23: Revolutions in Physics and Biology

Thanksgiving Break

November 28: BIG Science.

November 30: Information: Codes and Chips.

December 2: Section: Cold War History, by Billy Joel (**Weekly Paper Due**)

December 5: Monitoring the Globe.

December 7: Managing the Globe.

December 9: **Second Exam**

Readings

The Ancient World, and The Medieval World

Plato, "The Allegory of the Cave" from the *Republic*. *Science & Culture in the Western Tradition: Sources and Interpretations* ed. John G. Burke Scottsdale, AZ.: Gorsuch Scarisbrick, 1987, 7-9.

Aristotle "Inquiries into the Causes of Changes in Nature" from his *Physics* and his *Metaphysics*. Excerpted in *Science and Culture*, pp. 10-12.

Scholars and Craftsmen: The Renaissance

Leonardo da Vinci. Geometrical Studies (1514), in Otto Letze and Thomas Buchsteier, eds. Leonardo da Vinci: Scientist, Inventor, Artist (Ostfildern-Ruit: G. Hatje, 1997), 105.

Leonardo da Vinci. Design For a Machine Gun (1482), in Otto Letze and Thomas Buchsteier, eds. Leonardo da Vinci: Scientist, Inventor, Artist (Ostfildern-Ruit: G. Hatje, 1997), 143.

Leonardo da Vinci. Cannon Foundry (1487). Royal Library, Windsor (also available at: <http://www.kfki.hu/~arthp/html/l/leonardo/12engine/index.html>).

Leonardo da Vinci. "Da Vinci's sketch of projectile paths depending on mortar angle," <http://www.princeton.edu/~his291/>.

Leonardo da Vinci. "Architectural Drawings-- Projects of Towers," in Leonardo da Vinci (New York: Reynal & Company, 1956), 238.

Vesalius, "Preface" and "On Dissection of the Living Animals" from the *Fabrica*. Excerpted in Schwartz, George and Philip W. Bishop. *Moments of Discovery: The Development of Modern Science*. New York: Basic Books, 1958. 517-533.

Searching for the Ancient, Finding the New: Exploration

"World Map illustrating the routes and events of Spanish, Portuguese, English, French and Dutch Explorers" 1340-1600. William R. Shepherd, "[The Age of Discovery 1340-1600](#)," in Historical Atlas (New York: Henry Holt and Company, 1923), 107-108 (also available online at: http://www.lib.utexas.edu/maps/historical/history_shepherd_1923.html).

Alfred W. Crosby, "Space," Ch. 5 in *The Measure of Reality* (Cambridge UP) pp 95-108.

The Circulation of Knowledge

Adrian Johns, "The Birth of Scientific Reading," *Nature* **409** (18 January 2001): 287.

Elizabeth Eisenstein, "Defining the Initial Shift," chapter 2 in *The Printing Revolution in Early Modern Europe* (Cambridge UP, 1983): 12-40.

Circular Reasoning

Ptolemy, Selections from the *Almagest* excerpted in Schwartz, George and Philip W. Bishop eds. *Moments of Discovery: The Origins of Modern Science*. New York: Basic Books, 1958. pp. 174-179.

Osiander, "Anonymous Foreword to De Revolutionibus," *Science and Culture*, 95-99.

Copernicus, De Revolutionibus. excerpted in Moments of Discovery: The Origins of Modern Science. pp. 220-231.

Tycho and Kepler

Tycho Brahe, "Reform of Copernicus and Ptolemy." *Science and Culture*. pp. 99-102.

Johannes Kepler. *Mysterium Cosmographicum* (The Secret of the Universe) Trans. A.M. Duncan, Republished New York: Abaris Books, 1981. (Orig Published, 1596) pp. 34-35, 48-49, 106-107, 115, 117, 119.

Johannes Kepler. "Selenographical Appendix" to the *Somnium*, trans. Patricia Frueh Kirkwood, in John Lear. *Kepler's Dream*. Berkeley and Los Angeles: University of California Press, 1965. pp. 165-182.

Revolutionary Politics: Galileo

Galileo Galilei. *Sidereus Nuncius* (*The Sidereal Messenger*), Trans. Albert Van Helden. Chicago: The University of Chicago Press, 1989. (Orig. published 1610.) pp. 35-38, 64-66.

Galileo Galilei. *Dialogue Concerning the Two Chief World Systems*. (Orig. published 1629) excerpted in William S. Knickerbocker ed. *Classics of Modern Science*. Boston: Beacon Press, 1962. pp. 36-45.

"Galileo and the Conflict over Holy Scripture" from *Science and Culture*, 107-111.

Maurice A. Finocchiaro ed. *The Galileo Affair: A Documentary History*. Berkeley: The University of California Press, 1989. pp. 262-3, 276-279, 286-293.

Searching for the Truth: Science in the Catholic Church

John Heilbron, "Introduction," in [The Sun in the Church](#) (Harvard UP) pp 3-5, 21-23.

Methods for Truth: Descartes and Bacon

Francis Bacon. "Aphorisms on the Interpretation of Nature and the Empire of Man" from the *Novum Organum* reprinted in Schwartz and Bishop, *Moments of Discovery: the Origins of Science*, pp. 37-42.

René Descartes. "Rules for the Direction of the Mind." *Science and Culture*. pp. 126-127.

René Descartes. "Man a Machine." *Science and Culture*. pp. 129-130.

René Descartes. "Of the Visible Universe." from *Principles of Philosophy*. Trans. Valentine Rodger Miller and Reese P. Miller. Holland: D. Reidel Publishing Co., 1983. (Orig. published 1644) pp. 91-97.

René Descartes. "Vortices," from *The World or a Treatise on Light* (*A History of Science in Society: From Philosophy to Utility* (Toronto: Broadview, 2004), 153.

The Royal Society

"Boyle, Robert (1627-1691)," <http://www.chemcool.com/biography/boyle.htm>;
"[Boyle's] Air-Pump Designed by Robert Hooke. . . Described in Robert Boyle, *New Experiments . . . Touching the Spring of Air, and its Effects* (1660) (also available at: <http://www.bbk.ac.uk/Boyle/>).

Stephen Inwood, *The Man Who Knew Too Much*. London, Macmillan, 2002. pp. xvii-xxv.

Robert Hooke. "Observ. LIII. Of a Flea." *Micrographia* (1664) facsimile republished, New York: Dover Publications, 1961 pp. 175-179; pp. 210-211.

Robert Hooke. "A Contrivance to make the Picture of Any Thing Appear on a Wall Cub-Board, or within a Picture Frame." *Philosophical Transactions of the Royal Society*, Vol.3 (1663) 741-3.

Robert Hooke. "An Account of an Experiment Made by Mr. Hook, of Preserving Animals Alive by Blowing through Their Lungs with Bellows." *Philosophical Transactions of the Royal Society* Vol. 2 (1666-1667). 539-540.

Newton's World

Sir Isaac Newton. *Mathematical Principles of Natural Philosophy and his System of the World*. (*Principia Mathematica*) (Orig. published, 1686) Trans. Andrew Motte, reprinted Berkeley: University of California Press, 1962. pp. xiii-xviii, 13-15.

Voltaire, "Letter XIV: On Des Cartes and Sir Isaac Newton" and "Letter XV: On Attraction" from *Letters concerning the English Nation* ed. Nicholas Cronk. Oxford: Oxford University Press, 1994. (Orig. published, 1733) pp 61-75

Enlightenment: Mechanical Spirit

"Automata" from Diderot, D'Alembert eds. *Encyclopedia* trans. and selected Nelly S. Hoyt and Thomas Cassirer. Indianapolis: The Bobs Merrill Co. Inc., 1965. pp. 19-23.

Thomas Jefferson, *The Declaration of Independence*, 1776.

Jonathan Swift. "The Grand Academy of Lagado" from *Gullivers' Travels* (1726) reprinted New York: W.W. Norton & Company, 2002. 151-158.

Image: “Systeme Figure des Connoissances Humanes” from Diderot and D’Alembert’s Encyclopedie.

The Order of Things

Carolus Linnaeus, “Linnaeus on the Sexual System of Classification” from Dampier and Dampier eds. *Readings in the Literature of Science* (1959) pp.188-195.

Notes on the *Scala Naturae* (the “Great Chain of Being”) made by Dr. Mark Adams.

Romantic Science

Notes on the Works of Jean Baptiste-Pierre-Antoine de Monet de Lamarck made by Dr. Mark Adams.

Text of the Last Movement of Beethoven’s 9th Symphony, (1824) Taken from Friedrich Schiller’s *Ode to Joy*, (1785).

Digging and The meanings of Fossils

Charles Lyell, "Frontispiece," in Principles of Geology (10th ed.) (London: John Murray, 1867).

Charles Lyell. Excerpts from *Principles of Geology* (1833) in Kirtley F. Mather and Shirley L. Mason, *A Source Book in Geology, 1400-1900*. Cambridge, Mass.: Harvard University Press, 1939. pp. 263-265.

Wm. Parker Foulke. Description of the Discovery of the Hadrosaurus. *Proceedings of the Academy of the Natural Sciences*. (Nov. 1858) pp. 213-222.

"Hadrosaurus Foulkii," in Leonard Warren. Joseph Leidy: The Last Man Who Knew Everything (New Haven: Yale University Press, 1998), 86.

Darwin’s Century

William Paley. *Natural Theology*. Ed. Frederick Ferré. Indianapolis: The Bobs-Merrill Co., 1963. (Orig. Published 1802) pp. 3-6, 13-17.

Thomas Robert Malthus. *An Essay on the Principle of Population*. London: Penguin Books, 1970. (Orig. published, 1798) pp. 67-72.

Image: Map -- The Voyage of the Beagle.

Charles Darwin. “Organs of Extreme Perfection and Complication” (The Eye” from *On the Origin of Species* First Edition. (Orig. published, 1859) pp.186-189.

Charles Darwin. *On the Origin of Species* excerpts from *Science and Culture*, pp. 219-222.

Diagram from *On the Origin of Species*, 1859.

“The Century of Progress”?

Herbert Spencer. “Progress: Its Law and Cause” *Science & Culture*, pp. 223-227

Auguste Comte “The Positive Philosophy of Auguste Comte.” Trans. Harriet Martineau. (Orig. published, 1853) in *Science in the Nineteenth Century: An Anthology*. Ed. A.S. Weber. Peterborough, ON: Broadview Press, 2000. pp. 205-208.

Excerpts from Mike Davis, *Late Victorian Holocausts*. (New York: Verso, 2001.)

Cells and Germs

Case Study: Louis Pasteur and Spontaneous Generation. Excerpts from Pasteur’s “Memoir on the Organized Corpuscles which Exist in the Atmosphere.” Reprinted in James Bryant Conant ed. *Harvard Case Histories in Experimental Science: Vol 2*. Cambridge, Mass.: Harvard University Press, 1957. pp.494-496, 502-503, 509-513.

Matter and Energy

Hermann Von Helmholtz. “The Application of the Law of the Conservation of Force to Organic Nature.” (Orig. published, 1861) *Selected Writings of Hermann von Helmholtz* ed. Russel Kahl. Middletown, Conn.: Wesleyan University Press. pp.109-121.

The Quickening: Revolutions in Biology and Physics

Bertrand Russell. “The ABC of Relativity.” *Science and Culture*. pp. 244-247.

T.H. Morgan. “The Mechanism of Heredity: Part I” *Nature*. (February 23, 1922) 109:2730, pp. 241-244.

Chandak Sengoopta. “Tales from the Vienna Labs: The Eugen Steinach-Harry Benjamin Correspondence” *Newsletter of the Friends of the Rare Book Room, The New York Academy of Medicine*. (Spring, 2000) pp.1-7.

Big Science

Derek J. De Solla Price. *Little Science, Big Science ... and Beyond*. New York: Columbia University Press, 1986. 1-29.

Letter: Albert Einstein to President Franklin Delano Roosevelt, 1939.

Peter Galison, “The Many Faces of Big Science,” in *Big Science: The Growth of Large-Scale Research*, edited by Peter Galison and Bruce Hevly (Palo Alto: Stanford UP, 1992).

“Information: Codes and Chips”

Winston Churchill. “Iron Curtain Speech.” (1946) *The Nuclear Age Reader*. pp. 32-34.

Andrei Zhdanov. "Report on the International Situation to the Cominform." (1947) *The Nuclear Age Reader*. pp. 47-48.

Lewis Strauss. "Letter to President Truman." (1949) *The Nuclear Age Reader*. pp. 71-72.

President Harry Truman. "Authorization of H-Bomb" (1950) *The Nuclear Age Reader*. p. 72.

J.D. Watson and F.H.C. Crick. "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid" *Nature*. April 25th, 1953, pp. 737-8.

"Clue to Chemistry of Heredity Found." *New York Times*. Jun 13, 1953, p. 17.

Monitoring the Globe

"Round the World: In 96 Minutes," *New York Times* Editorial, p. 93, 10/06/1957.

Managing the Globe

Richard Elliot Benedick, "Lessons from History," and "The Science: Models of Uncertainty," Chs. 1 & 2 in *Ozone Diplomacy: New Directions in Safeguarding the Planet* (Harvard UP, 2nd edition, 1998): pp. 1- 24.

Assignments

Weekly Assignment 1

Due Date: Sept. 14th

Choose a common household object and write two paragraphs about it. In the first paragraph, describe it in the way that a Platonist would see it. In the second, describe it in the way that an Aristotelian would see it. Your answer should be 1-page long, typed in a 12 pt. standard font (e.g. Times New Roman).

Weekly Assignment 2

Due Date: Sept. 21st

Draw a map of your favorite place. In a paragraph or two, explain who your map is for, and how they should use it. Discuss the choices you made in deciding what to represent, and how to depict it.

Weekly Assignment 3

Due Date: Sept. 28th

[Choose one of the following.]

You are a court astronomer in the sixteenth century, devoted to the Ptolemaic system. Based on this week's readings, what about Copernicus's system might you find appealing? Objectionable?

– or –

Copernicus and Ptolemy employ different forms of proof to advance their arguments. Choose a topic that both discuss (e.g. why the universe is spherical). How does their use of evidence differ?

Weekly Assignment 4

Due Oct. 12th, Handed Out Oct. 7th

Choose any animal and describe it, first as you think Descartes would, and then as you think Hooke would.

Weekly Assignment 5

Due Date: Oct. 26th (Handed Out After Midterm on 19th)

In 1771, the Philadelphia clockmaker and astronomer David Rittenhouse completed his famous Orrery, an object which embodies the Enlightenment fascination with clockwork

mechanisms. This Orrery is now in Van Pelt Library. Find it, spend time with it and think about it. Report your thoughts and findings.

Weekly Assignment 6

Due Date: Nov. 9th (Handed Out Nov. 4th)

What are the connections between the city of Philadelphia and the history of fossil-hunting? Do some digging on the web and tell us your more interesting findings.

Weekly Assignment 7

Due Date: Nov. 16th (Handed Out Nov. 11th)

Pick an object in your room for which you know the place it was made. Was it made within a few miles of Philadelphia (or wherever you first got it)? Discuss how it came to be here, with reference to who made it, how it was probably made, and how much energy it took to get to your room.

Weekly Assignment 8

Due Date: Dec. 1st (Assigned Nov. 18th)

One of the most popular musicians of the Cold War, Billy Joel wrote several songs that provide beautiful snapshots of the personal effects of macro-history. In this assignment, we will look at one of them, "We Didn't Start the Fire," a 1989 hit. Your TA will assign you two or three references from the song. Please research and write a concise paragraph on each reference. The paragraph should capture the importance and meaning of the reference, putting the event into a bit of context. If relevant, it should also point out any connections between the reference and science and technology.

In section, we'll pull these references together, listen to the song, and discuss its meaning in 1989 and today.

Project: *Observing the Moon Through a Telescope*

Due Date: Oct. 7th (Announced Sept 16th)

The first observations of the Moon through a telescope proved shocking to those accustomed to regarding the Moon as a smooth, featureless globe. Over the next three weeks, working in groups, you will have the opportunity experience some of the excitement and challenge of these early observations by viewing the Moon through a telescope similar to those Galileo Galilei and Johannes Kepler utilized for their observations.

Each student will observe the Moon on two or three *different* evenings *each* week, and sketch those observations on a log sheet of your own design. Your log will include a total of at least 6 observations. For the first week, simply make your observations without the telescope; see the moon unaided. Note what it looks like, and sketch it. For the second and third weeks, use the telescopes to look at the moon. Your logs can include whatever

observations or reflections you choose to include. Like Galileo, imagine that you are producing something that will be shared publicly and that aims to prove a claim about the moon. Some nights will be cloudy; if you can see nothing, that's all right. Note it in your log, or describe or illustrate how the moon shines through clouds.

At the end of the log, write a page or two reflecting on the difficulties you experienced, things you found unexpected, or things you learned from the project. The readings on Galileo and Kepler may help you to think about this project more personally.

Students are encouraged to observe in groups but all students should make their own observations and drawings.

Telescopes

The instruments for this project are simple refracting telescopes patterned on Kepler's original design. Details may be found at: http://www.hssonline.org/teach_res/COE/activities/telescope.html. The telescope's eyepiece is the smaller of the two lens openings, and focus is achieved by extending or collapsing the two cylinders that comprise the telescope. Eyeglass wearers should be able to use the telescope with or without their glasses.

Students will form groups of three-to-five people, and each group will share a telescope. Telescopes are available from your Teaching Assistant, and should be returned at the conclusion of the exercise. If you wish to buy your own telescope, visit: <http://www.starlab.com/index.html>.

It may be a challenge to focus your telescope and hold it steady. You'll probably need to experiment. The history of science museum in Florence has parts of Galileo original telescope; you can see how he overcame these same challenges.

Where to View the Moon

You may observe the Moon from any convenient location, indoors or out, including: a dimly lit room, your dorm's lounge, or a campus courtyard or green. *Stay off the roof* — you will not need to be on one to complete this project.

Safety and Comfort

If you observe outside at night, stay on campus, be aware of your surroundings, always stay within sight of other people, and observe in a group, if possible. If observing outside in cool weather, dress more warmly than you normally would, as you may be outside, standing still, for longer than you think. Be sure to bring with you: the log sheet; a pencil; an eraser; a flashlight; and something to lean on when writing. Finally, ***NEVER LOOK AT THE SUN THROUGH YOUR TELESCOPE! A number of early modern astronomers went nearly blind from looking at sunspots.***