

Timeline

2000-500 B.C.E.	Babylonian civilization
600-580 B.C.E.	Thales of Miletus flourishes
6th c. B.C.E.	Pythagorean School founded
399 B.C.E.	Socrates executed
388 B.C.E.	Plato founds the Academy
384 B.C.E.	Aristotle born at Stagira
348/7 B.C.E.	Death of Plato
335 B.C.E.	Aristotle founds the Lyceum at Athens
332 B.C.E.	Alexandria founded
323 B.C.E.	Alexander the Great dies after creating a vast empire Aristotle flees Athens and dies a year later
c. 300 B.C.E.	Museum and Library founded at Alexandria; Euclid flourishes
212 B.C.E.	Romans conquer Syracuse; Archimedes killed
86 B.C.E.	Romans sack Athens
44 B.C.E.	Start of Julian calendar; Julius Caesar murdered
30 B.C.E.	Rome annexes Hellenistic Egypt
79 C.E.	Pliny the Elder killed in the eruption of Vesuvius
150	Ptolemy flourishes
c.162-8	St. Justin martyred at Rome
c.270	Library of Alexandria destroyed during civil warfare
313	Edict of Milan legalizes Christianity in the Roman Empire
325	Ecumenical Council of Nicaea
354-430	Life of St. Augustine
410	Rome sacked by Alaric
476	Last of the (Western) Roman emperors slain by the barbarian Odoacer
524	Boethius executed
c.530	St. Benedict writes the Rule, origin of the Benedictine Order
622	Muhammed flees to Medina from Mecca beginning of Islamic calendar
711-718	Spain annexed to Islamic Empire; Muslim fleet destroyed at Constantinople by Greek fire
750-1000	Translation movement into Arabic
756	Umayyad caliphate established in Spain
762	Al-Mansilr founds Baghdad as seat of Abbasid caliphate
782	Patriarch Timothy I debates the nature of Christ with Caliph al-MahdI using the methods of Aristotle's Topics
800	Charlemagne crowned Holy Roman Emperor
c.1020	School of Chartres founded
1020s-1030s	Al-Hazen (Ibn al-Haytham) active in Cairo
1085	Christian forces capture Toledo
1099	First Crusade takes Jerusalem; Latin Kingdom established
1125-1200	Latin translation movement; texts from Arabic enter Europe
1187	Saladin captures Jerusalem
c.1200	University of Paris established; Oxford, about twenty years later
1205	St. Dominic founds the Order of Preachers (Dominicans)
1209	St. Francis founds the Order of Friars Minor (Franciscans)
1258	Baghdad sacked by the Mongols

1275	Alphonsine Tables compiled
1277	Condemnation of 1277; 219 propositions condemned at the University of Paris
1270s-1280s	Willem of Moerbeke translates Aristotle from Greek
1330s	“Oxford Calculators” active
1348	Black Death (bubonic plague) arrives in Europe; within a few years, it kills one-third of the European population
1400-1500	Humanism develops as a major intellectual force, first in Italy, then elsewhere
c.1450	Johannes Gutenberg invents moveable-type printing
1452	Constantinople falls to the Turks
1492	Columbus lands in the New World; last of the Muslims expelled from Spain
1517	Luther nails up his theses
1522	Magellan's expedition circumnavigates the globe
1543	Copernicus' <i>De revolutionibus</i> and Vesalius' <i>De fabrica</i> are published
1545-1563	Council of Trent
1560s-1570s	Paracelsus' unpublished works begin to appear in print
1572	“Tycho's new star” appears in Cassiopeia; he begins construction of Uranibourg in 1576
1577	A bright comet appears and is calculated to be superlunary
1582	Start of Gregorian calendar
1586	Fontana successfully moves the Vatican obelisk
1588	Tycho proposes the Tyconic system
1600	Gilbert's work on the magnet is published
1603	Accademia dei Lincei founded at Rome
1607	Jamestown founded in Virginia
1609	Kepler proposes ellipses as planetary orbits
1610	Galileo's telescopic discoveries appear in the <i>Sidereus Nuncius</i>
1620	Plymouth colony established in Massachusetts
1632	Galileo's <i>Dialogues on the Two Chief World Systems</i> published; the next year, he is condemned
1642	Birth of Newton, death of Galileo
1648	Van Helmont's works published
1658	Gassendi's natural philosophical system published
1660	Royal Society of London founded; given Royal Charter in 1662
1666	Academie Royale des Sciences founded in Paris; Paris Observatoire founded the following year
1687	Newton's <i>Principia</i> published
1699	Paris Academy reorganized

Glossary

Aggregation notation (see place notation): A method of writing numbers that depends upon numerals with fixed values that are to be added up to provide the desired total value, for example, Roman numerals.

Ancilla: Latin for “handmaiden”; compare the English derivative *ancillary*. Used in the history of science to describe the status of the natural sciences relative to theology in the Middle Ages, as enunciated most influentially in the writings of St. Augustine and other Patristics.

Anima motrix: Literally, “motive soul”; according to Johannes Kepler, a motive power located in the sun that pushes the planets around in their orbits.

Archeus: A term coined by Paracelsus but further developed by Van Helmont. In the latter author, the *archeus* was a guiding spiritual principle that maintained the processes and functions of living bodies.

Astrolabe: An observational and calculating instrument, originally of Hellenistic origin but developed in the Arabic world, which allows for the measurement of elevations, the calculation of local time and the rising and setting of bright stars and the sun on any day, and astrological information.

Carolingian: Of or relating to the period or culture under Charlemagne.

Circumscription: In geometry, the practice of drawing one figure as tightly as possible around another; for example, a circle circumscribed around an isosceles triangle touches it at three points.

Collegio Romano: The Roman College of Jesuits, opened in 1565 in Rome; it was both an educational institution and seminary, as well as a place where notable Jesuits carried out natural philosophical studies.

Condemnation of 1277: An order issued in 1277 by Etienne Tempier, the bishop of Paris, banning the masters of the University of Paris from holding or defending 219 propositions considered false, many of them deriving from Aristotle or contrary to Christian teaching on free will, God's omnipotence, and so on.

Corpus: Latin for *body*, in literary terms, the *body of writings* produced by an author.

Council of Trent: A highly significant meeting of Catholic theologians and hierarchy that took place in the northern Italian city of Trento from 1545 to 1563. The purpose was to address the problem of Protestantism by internal reforms, regularization of doctrine, and measures to prevent further schism.

Creatio ex nihilo: “Creation out of nothing”, an article of Christian faith stressing that God alone is eternal and is the creator of everything.

Deferent: The primary orbit of a planet around its center of motion; the deferent carries the epicycle.

Demiurge: Plato's craftsman god, an eternal but not omnipotent being who organized (equally eternal) matter into the world using the Forms as the blueprint.

Determinism: The idea that future events are pre-determined; there is no free will.

Dualism (Cartesian dualism): The idea that the human being is composed of two distinct entities, a material body and an immaterial soul.

Eccentric: A planetary orbit that is not centered on the geometrical center of the cosmos.

Epicycle: The secondary orbit of a planet, centered on the primary orbit (deferent) around the center of motion. The deferent carries the epicycle; the epicycle carries the planet.

Epistêmê: Greek for “knowledge”, specifically the knowledge of what and why a thing is (for example, in medicine, *epistêmê* would be knowledge of the disposition of the internal organs and their functions; compare *technê*).

Epistemology: The study of knowledge; epistemology studies what we know (or can know) and how we know it (or think we know it).

Error of the double truth: An error condemned in 1277 that holds that the same proposition may be true in theology but false in philosophy.

Experimentum crucis: A term used by Newton, literally “experiment of the crossroads”, to describe an experiment that allows one to decide definitively between two competing theories.

Forms, Plato's theory of: The notion that material objects are but dim reflections or shadows of idealized immaterial Forms that exist outside of the physical world; these Forms are eternal and unchanging and are vaguely remembered by us from the time before our birth.

Geocentric: Literally, “earth-centered”; used to refer to the Aristotelian, Ptolemaic, and Tychonic systems in which the earth is at the center of the cosmos.

Geokinetic: Literally, “earth moving”; used to refer to cosmic systems in which the earth is in motion, such as the Copernican system.

Geostatic: Literally, “earth stationary”; used to refer to cosmic systems in which the earth is at rest.

Gnômôn: A stick or pole fixed vertically in the ground for the purposes of measurement, surveying, or astronomical study. For example, the length of the *gnômôn* and the shadow it casts can be used to calculate the elevation of the sun above the horizon. The spine in the center of a sundial is also called a *gnômôn*.

Hadith: An accepted and attested saying of the Prophet Muhammed.

Heliocentric: Literally, “sun-centered”; used to refer to the Copernican system. (Actually, Copernicus' system has the sun slightly off center and is more rigorously labelled heliostatic, that is, with a stationary sun.)

Hellenistic: An adjective describing the Greek-dominated world and culture created by Alexander's conquests.

Hexameral literature: Theological writings that comment on the first chapter of Genesis (the “Six Days” of Creation), an important locus for natural philosophical inquiry during the Middle Ages.

House of Wisdom (*Bayt al-Hikmah*): An institution founded in Baghdad in the eighth or ninth century; it presumably included a depository of records and texts and appears to have been a locus of scholarly activity.

Humanism: A broad-based intellectual movement of the Renaissance characterized by a love of classical antiquity; an interest in texts, textual purity, and elegant literary style; contempt for Scholasticism; and an interest in active civic life.

Hylomorphism: The Aristotelian doctrine that everything is composed of matter (prime matter, or *hylé*) together with form (*morphé*); the matter is the amorphous stuff out of which the thing is made, while form is the constellation of all the qualities of the thing.

Impetus: In medieval physics, the “impressed motion” of an object that keeps it in motion after it has lost contact with the mover. Akin (but not identical) to the modern idea of momentum.

Ius ubique docendi: “The right of teaching anywhere”, a right bestowed on recipients of a master's degree in the Middle Ages, guaranteeing them the right to take up residence and offer classes at any university.

Jesuits: The Society of Jesus, a religious order of priests founded by St. Ignatius Loyola and officially recognized in 1540. Their origin and work was initially tied closely with the Counter Reformation; Jesuits paid particular attention to education and scholarly pursuits.

Kinematics: A branch of physics dealing with the study of moving bodies.

Libri naturales: A term given to certain books of Aristotle's that dealt specifically with natural phenomena, such as *On the Heavens*, the *Physics*, the writings on animals, and other (sometimes spurious) works.

Loadstone: A naturally magnetic iron mineral, known today as magnetite.

Madrassa: An Islamic school, generally connected to a mosque.

Magus: A practitioner or student of natural magic.

Mechanical philosophy: A collection of worldviews popular in the seventeenth century, characterized by the vision of the world as a machine in which the sole basis for natural phenomena was matter and motion.

Mercury-Sulphur theory: A theory on the composition of metals, proposed in the writings attributed to Jabir ibn-Hayyan, which states that metals are produced in the earth from the combination of two ingredients called Mercury and Sulphur.

Mesopotamia (lit. “between the rivers”): The area between the Tigris and Euphrates rivers, now largely within Iraq, home to several important civilizations during the first and second millennia B.C.E.

Minima naturalia: The smallest possible piece of a substance that retains the qualities of the substance.

Monism: The philosophical position that all the varied substances seen in the world are actually, at their fundament, composed of the same stuff.

Mozarabs: Christians of the Iberian peninsula who lived under Muslim rule. Natural magic: A body of knowledge dealing with the deployment of connections or sympathies/antipathies between objects in the natural world toward useful ends.

Natural place (natural motion): The Aristotelian idea that the four elements have specific places (based on their relative weights) in the sublunary world and move naturally toward those places.

Naturalism: The idea that phenomena in the natural world should be explained using natural causes, not the recourse to miraculous or direct interventions by God.

Occult quality: The hidden qualities of a thing (as opposed to the manifest qualities, namely, those that are recognizable by the senses).

Ontology: The study of being; ontology studies what exists and how it exists.

Parallax: An optical phenomena wherein objects that are closer to the viewer change their positions relative to objects that are further away when the vantage point of the viewer changes.

Philosophers' Stone: A substance prepared in the alchemical laboratory by a secret process which, when cast upon a quantity of molten metal, transmutes it in a few minutes into pure gold (or silver). The Philosophers' Stone is first mentioned in the writings of Hellenistic Egypt (c.300 C.E.) and was a chief pursuit of alchemists down to the 18th century.

Place notation (see aggregation notation): A method of writing numbers that depends upon numerals whose individual values are given by a combination of their inherent values and their places in the overall numeral (that is, whether in the “tens place” or the “hundreds place”), for example, Arabic numerals.

Platonic solids, or the “perfect polyhedra”: The five solid bodies that are composed entirely of identical faces which are regular polygons, namely, the tetrahedron (triangular faces), the cube (square faces), the octahedron (triangular faces), the dodecahedron (pentagonal faces), and the icosahedron (triangular faces).

Plenum: Latin for “full”; a description of the world in which there is no void space-the universe is absolutely full of matter. A view held by Aristotle and Descartes, among others.

Pluralism: The philosophical position that there is more than one material substratum for the varied substances seen in the world.

Presocratic: Dating from before the time of Socrates (d.399 B.C.E.), particularly to refer to a miscellaneous assemblage of Greek thinkers of the sixth to fourth centuries B.C.E.

Prime matter: In Aristotle's natural philosophy, the entirely quality-less “stuff” (*hylē*) of which everything is made; prime matter becomes a particular substance or object when wedded to a form (see hylomorphism).

Prisca sapientia: “Original wisdom”, the mass of knowledge which some believed that God had imparted to figures of great antiquity -often biblical patriarchs, such as Adam, Seth, Solomon, and others- and which had become gradually lost or corrupted over time.

Qibla: The direction Muslims face during formal prayer: originally toward Jerusalem but soon changed toward Mecca.

Quadrivium: The four mathematical arts of the classical Roman educational system (the seven liberal arts): arithmetic, geometry, astronomy, and music.

Reductionism: The idea that a maximum number of phenomena or a maximum amount of data should be explained by the minimum number of principles.

Retrograde motion: The backward (east to west) motion through the zodiac that the superior planets (Mars, Jupiter, and Saturn) appear to have during part of the year. It is caused (in modern terms) when the earth “laps” these planets in its annual journey around the sun.

Saving the phenomena: The idea, particularly important in pre-modern astronomy, that the prime function of theoretical systems is to explain the observed phenomena, rather than being necessarily literally true representations of the natural world.

Scholasticism: The philosophy and method of “the Schools”, namely the medieval university, based heavily on Aristotelian writings and logical principles and incorporating a formalized methodology of questions and responses.

Scriptoria: The workshop, usually at a monastic center, used for the copying of manuscripts.

Seminal reasons (*rationes seminales*): Active principles implanted in the world that organize matter into specific forms.

The Sentences: Four books of theological questions and answers written in the mid-twelfth century by Peter Lombard; nearly all subsequent medieval theologians wrote an orderly commentary on the Sentences. “Sentences” is a translation of the Latin *sententiae*, which is actually better rendered as “opinions.”

Sexagesimal: A mathematical system using a base of sixty, rather than ten as in our modern decimal notation.

Signatures (doctrine of signatures): The notion that God had “marked” natural objects with signs (“signatures”) that gave clues to their otherwise hidden powers, correspondences, and natures.

Substantial forms: In scholastic philosophy, the sum total of the qualities of a thing that make it what it is.

Syriac: A Semitic language of the Levant, the official language of several Christian liturgies and of the Nestorians.

Technê: Greek for craft or art; specifically, knowledge of how to do or produce something (for example, in medicine, *technê* would be the knowledge of how to perform a particular operation or cure a particular illness; compare episteme).

Transmutation: In alchemy, the conversion of one metal into another, usually a base metal (lead, tin, mercury, copper, or iron) into a noble one (gold or silver). See Philosophers’ Stone.

Tridentine: Of or relating to the Council of Trent.

Trivium: The three verbal arts of the classical Roman educational system (the seven liberal arts): grammar, rhetoric, and dialectic (or logic).

Tychonic system: A cosmological system proposed by Tycho Brahe in 1588 as an alternative to the Ptolemaic and Copernican systems. According to the Tychonic system, the earth is located at the center, the moon and sun move in orbits around the earth, but the planets revolve on orbits around the sun.

Zodiac: A narrow band in the sky to which the motions of the planets, sun, and moon are restricted. This band is traditionally divided into twelve constellations—the “natal” constellations, Aries to Pisces—and into twelve astrological “houses”—regions that govern particular aspects of terrestrial existence.

Bibliography

Essential Readings:

Note: The following texts can be considered the general “textbooks” and important primary sources for the course; they are intended to provide a set of more or less continuous readings relating to the lectures. However, the material covered in some of the lectures does not appear in these books; the supplementary readings below furnish more specific information-usually at a somewhat higher level.

Barnes, Jonathan. *Aristotle: A Very Short Introduction*. Oxford: Oxford University Press, 2000. This is the best quick introduction to Aristotle available; excellent overview and analysis.

Debus, Allen G. *Man and Nature in the Renaissance*. Cambridge: Cambridge University Press, 1978. A slim work intended as a textbook, covers material for Lectures Twenty-Four to Thirty-Three.

Finocchiaro, Maurice A. *The Galileo Affair: A Documentary History*. Berkeley: University of California Press, 1989. Contains not only translations of all the documents relating to Galileo's trials, but also an introduction with the most concise and balanced overview of the whole affair.

Galileo. *Sidereus Nuncius*, trans. Albert van Heiden. Chicago: University of Chicago, 1989. Galileo's announcement of his telescopic discoveries; highly readable way to encounter primary sources.

Grant, Edward. *The Foundations of Modern Science in the Middle Ages*. Cambridge: Cambridge University Press, 1996. A clear and comprehensive textbook for the Latin medieval section of the course, Lectures Thirteen and Seventeen through Twenty-Three; especially good on the subjects of the Latin translation movement, universities, and medieval physics and cosmology.

Gutas, Dimitri. *Greek Thought, Arabic Culture*. London: Routledge, 1998. There are no textbooks in English dealing with the history of Arabic science; however, this book gives an excellent, up-to-date, and insightful analysis of the adoption of Greek learning in the Islamic world, even though the level of discussion is somewhat high for a beginning student.

Henry, John. *The Scientific Revolution and the Origins of Modern Science*, 2nd ed. London: Palgrave, 2002. An outstanding and very short survey of seventeenth-century science. It is massively and unobtrusively referenced with the most up-to-date sources and, thus, can be a jumping-off point for further study of specific topics. Because it does not run in the same order as the lectures I suggest that listeners read the whole thing through after Lecture Thirty-Five as ' a summary review of Lectures Twenty-Four to Thirty-Five.

Lindberg, David C. *The Beginnings of Western Science*. Chicago: University of Chicago Press, 1992. A good and thorough textbook designed for undergraduates, used here as a mainstay of the first two units (Lectures One through Twenty-Four).

Lloyd, G. E. R. *Early Greek Science: Thales to Aristotle*. New York: Norton, 1970. The author is the accepted authority on ancient Greek scientific thought; excellent introduction to the content of Greek thought about the natural world.

---. *Greek Science after Aristotle*. New York: Norton, 1973. See the previous comment.

Plato. *Timaeus and Critias*, trans. Desmond Lee. New York: Penguin Classics, 1977. Good readable translation of the *Timaeus*.

Westfall, Richard S. *The Construction of Modern Science: Mechanisms and Mechanics*. Cambridge: Cambridge University Press, 1977. Parts of this work are quite dated now, but it still contains a good presentation of the essentials of the mechanical philosophy.

William of Conches. *A Dialogue on Natural Philosophy (Dragmaticon Philosophiae)*, ed. Italo Ronca and Matthew Curr. South Bend, IN: University of Notre Dame Press, 1997. A very readable translation that provides a fine sense of the style and motivation of a (non-Scholastic) medieval treatise on natural philosophy.

Supplementary Readings:

Applebaum, Wilbur, ed. *Encyclopedia of the Scientific Revolution: From Copernicus to Newton*. New York: Garland Publishing, 2000. An extremely useful reference source for the third unit of this course, hundreds of concise, up to-date entries written by leading scholars and intended for students. If you want to acquire one reference source for the history of the Scientific Revolution, this is it.

Aristotle. His entire corpus appears in the Loeb Classical Library editions where the translations run the gamut from good to bad in terms of readability and accuracy. There are a slew of Aristotle translations out there, and it is probably best to buy or borrow them like shoes-try them on, walk around a bit, and, if they seem uncomfortable, there is probably another one to try on. Also try a “reader” which contains “key” selections from Aristotle's writings; there are quite a few available, see below, for example, Irwin and Fine.

Ashworth, William B., Jr. “Natural History and the Emblematic World View”, in *Reappraisals of the Scientific Revolution*, edited by David C. Lindberg and Robert S. Westman, pp. 333-365. Cambridge: Cambridge University Press, 1990. A clear exposition of the changes in the way the natural world and its objects were viewed in the Renaissance.

Augustine. *The Confessions*, trans. by R. S. Pine-Coffin. New York: Penguin Books, 1961. Most readable translation of this important work; easily available. Follow St. Augustine on his circuit of the late classical world. Between the pious exclamations, this book gives a vivid view of the intellectual/philosophical marketplace of 400 B.C.E. and St. Augustine's real indebtedness to classical thought.

Bacon, Francis. *Selected Philosophical Works*, ed. Rose-Mary Sargent. Indianapolis, IN: Hackett, 1999. Good translation and collection, containing selections from most of Bacon's works that deal most closely with his method and his impact on the history of science.

Benson, Robert L. and Giles Constable, eds. *Renaissance and Renewal in the Twelfth Century*. Toronto: University of Toronto Press, 1999. A recent and lengthy work updating the classical study by Haskins. It consists of twenty-six papers which cover the broad range of subjects which underwent dramatic change during the twelfth century.

Cadden, Joan. “Science and Rhetoric in the Middle Ages: The Natural Philosophy of William of Conches”, *Journal of the History of Ideas* 56, (1995): 1-24. Fine contextualization and exposition on the primary reading listed above from William of Conches.

Casson, Lionel. *Libraries in the Ancient World*. New Haven: Yale University Press, 2001. Very readable overview of the development of libraries in antiquity.

Copenhaver, Brian P. "Natural Magic, Hermeticism, and Occultism in Early Modern Science", in *Reappraisals of the Scientific Revolution*, edited by David C. Lindberg and Robert S. Westman, pp. 261-301. Cambridge: Cambridge University Press, 1990. Important analysis of how natural magic functioned in the Renaissance and clarification of the role of the Hermetic corpus; fairly high level but fascinating.

---. *Hermetica: The Greek Corpus Hermeticum and the Latin Asclepius in a New English Translation with Notes and Introduction*. Cambridge: Cambridge University Press, 1992. Best translation of the Hermetic corpus, with an extremely detailed and expert introduction.

Copernicus, Nicolas. *On the Revolutions*, tr. by Edward Rosen. Baltimore: Johns Hopkins Press, 1978. An excellent translation of *De revolutionibus*, including all the important front matter and with a helpful introduction and annotations.

Crombie, A. C. *Robert Grosseteste and the Origins of Experimental Science, 1000-1700*. Oxford: Clarendon Press, 1953. Slightly dated at some points but still a clear exposition of Grosseteste's work and influence.

Dawson, Christopher. *Mission to Asia*. Toronto: University of Toronto Press, 1998. Very readable translations of the original accounts compiled by the Franciscan friars who journeyed to Mongolia in the middle of the thirteenth century. Absolutely fascinating.

Dear, Peter, ed. *The Scientific Enterprise in Early Modern Europe: Readings from Isis*. Chicago: University of Chicago Press, 1996. A collection of over a dozen articles from *Isis*, the journal of the History of Science Society. The volume makes a good "reader" for those interested in more advanced and detailed discussions of particular events or characters of the Scientific Revolution. (See the similar reader volume by Shank, ed., below.)

Dhanani, Alnoor. *The Physical Theory of Kalam: Atoms, Space and Void in Basrian Mu'tazili Cosmology*. Leiden: Brill, 1994. Fascinating analysis of atomistic doctrines among the early *mutakallimiin*; a difficult text to be sure (it began as a Ph.D. dissertation), but so is the topic. Provides considerable reward to a patient and committed reader.

Dibner, Bem. *Moving the Obelisks*. Norwalk, CT: Burndy Library, 1991. Short and entertaining study of the moving of obelisks from antiquity to the modern era; profusely illustrated, including fold-out plates that are facsimiles from Fontana's sixteenth-century account of moving the Vatican obelisk.

Dick, Steven J. *Plurality of Worlds: The Origins of the Extraterrestrial Life Debate from Democritus to Kant*. Cambridge: Cambridge University Press, 1982. Fascinating account of the varied historical views on the possibility of extraterrestrial life.

Dobbs, Betty 10 Teeter. *The Janus Faces Of Genius: The Role of Alchemy in Newton's Thought*. Cambridge: Cambridge University Press, 1991. An attempt to synthesize the disparate elements of Newton's interests and activities into a unified portrait of his scientific motivations.

---. "Newton as Final Cause and First Mover", *Isis* 85 (1994): 633-643. The text of the Distinguished Lecture given by this expert on Newton's alchemy to the History of

Science Society in 1993. This short paper is extremely readable for all students of this course and does a fine job of summarizing the groundbreaking re-evaluation of Newton's position in the history of science (particularly in regard to his alchemy and theology) advanced by Dobbs.

Eamon, William. "Technology as Magic in the Late Middle Ages and the Renaissance," *Janus* 70 (1983): 171-212. A very interesting view of the "wonderful" aspect of technology, with excellent examples and illustrations, written in an engaging style.

Galileo. *Dialogue on the Two Chief World Systems*. There are two translations currently available. The older one by Stillman Drake is *Dialogue Concerning the Two Chief World Systems, Ptolemaic and Copernican*. New York: Modern Library, 2001. A newer translation and abridgement along with helpful up-to date commentary is by Maurice Finocchiaro, *Galileo on the World Systems: A New Abridged Translation and Guide*. Berkeley: University of California Press, 1997.

Galileo, *Two New Sciences*, tr. Henry Crew and Alfonso de Salvio. New York: Dover, 1954. An older translation, but readable and widely available in many editions.

Gies, Frances, and Joseph Gies. *Cathedral, Forge and Waterwheel: Technology and Invention in the Middle Ages*. New York: Harper/Collins, 1994. A fine work for the general reader covering late classical and medieval technology.

Gilbert, William. *On the Magnet*. New York: Basic Books, 1958. An older translation but readable and widely available in many editions.

Grafton, Anthony. *Cardano's Cosmos: The Worlds and Works of a Renaissance Astrologer*. Cambridge, MA: Harvard University Press, 1999. View of the life and thought of an important Renaissance figure.

Grant, Edward, ed. *A Source Book of Medieval Science*. Cambridge, MA: Harvard University Press, 1974. May be a little difficult to find but contains more than a hundred translated excerpts from medieval authors (Latin and Arabic) with annotations and commentary. Particularly strong in cosmology and physics.

Hare, R.M. *Plato*. Oxford: Oxford University Press, 1996. A very brief survey of Plato's ideas. The author is a moral philosopher, and so his analysis centers more on aspects of Plato's thought than on topics strictly of interest to the historian of science.

Haskins, Charles H. *The Renaissance of the Twelfth Century*. Cambridge, MA: Harvard University Press, 1927. The classic work on the subject. Frequently reprinted and easily available; covers a wide range of topics in twelfth-century history, not just history of science.

Hellman, C Doris. *The Comet of 1577: Its Place in the History of Astronomy*. New York: AMS Press, 1971. Analysis of the importance of comet observations by Tycho and others and how they affected the prevailing Aristotelian view of the cosmos.

Hugh of St. Victor. *Didascalicon*, ed. Jeremy Taylor. New York: Columbia University Press, 1991. Good primary source in which to sample the heights reached by the Platonic strain of Christian thought and the emphasis placed on education by the medieval Christian schools. Can be a bit difficult to penetrate at points, but rewarding (and provocative!) to the patient modern reader.

Huizinga, Johan. *The Autumn of the Middle Ages*. Chicago: University of Chicago Press, 1996. A classic, dealing predominantly with art history yet useful for the student of this course in terms of creating the cultural atmosphere at the end of the "Middle Ages."

Hutchison, Keith. "What Happened to Occult Qualities in the Scientific Revolution?" *Isis* 73 (1982): 233-253. Provides an excellent description of the meaning and identity of "occult qualities" in late Aristotelian thought and their often-surprising fate in the Scientific Revolution, including the co-opting of such qualities by the mechanical philosophy. (Also reprinted in the Dear collection, above.)

Irwin, Terence and Gail Fine. *Aristotle: Selections*. Indianapolis: Hackett Publishing, 1995. Reading all the way through anyone work by Aristotle on one's own takes a bit of fortitude; this book provides important selections from about fifteen of Aristotle's books. The range includes his logic and ethics, but also selections from some of libri naturales (but, unfortunately, nothing from *On the Heavens*). The translations are generally good and readable.

Kahn, Charles H. *The Art and Thought of Heraclitus*. Cambridge: Cambridge University Press, 1979. Detailed analysis and text (Greek and English) of each fragment surviving from my favourite Pre-Socratic philosopher.

Kargon, Robert H. *Atomism in England from Harriot to Newton*. Oxford: Clarendon Press, 1966. Analysis of the various atomistic views in England with brief biographical sketches of their promoters-excellent for following the history of this important idea in England up to Newton.

Kirk, G. S., J. E. Raven, and M. Schofield. *The Pre-Socratic Philosophers*. Cambridge: Cambridge University Press, 1983. One of the classic works on the Pre-Socratics: texts, translations, and analyses. Hard to read through, more a work of reference. (See Wheelwright, below.)

Landels, J. G. *Engineering in the Ancient World*. Berkeley: University of California Press, 1981. Emphasis on hydraulic engineering, weapons, and modes of transport in the ancient world. Overview of the technological work found of Hero, Vitruvius, Frontinus (first century C.E. waterworks engineer for the city of Rome), and Pliny.

Lawrence, C H. *The Friars*. London: Longmans, 1994. Account of the origin and work of the Dominicans and Franciscans in the Middle Ages.

Leff, Gordon. *Paris and Oxford Universities in the Thirteenth and Fourteenth Centuries*. Huntington, NY: Krieger Publishing, 1975. The standard work on the medieval university; detailed analysis of the origins of the northern universities, fascinating detail about curricula and student life, as well as intellectual developments at each locale.

Lindberg, David C *Roger Bacon's Philosophy of Nature*. Oxford: Clarendon Press, 1983. Critical editions and translations of Roger Bacon's works *On the Multiplication of Species* and *On Burning Mirrors*, together with biographical material on Bacon and analysis of his intellectual development and contributions. Bacon's text can be quite challenging for a twenty-first century reader, but brush up on your medieval Aristotelian terminology and optics and plunge in!

Lindberg, David C, ed. *Science in the Middle Ages*. Chicago: University of Chicago Press, 1978. A collection of essays by eminent scholars on medieval history of science; essays cover technology, the translation movement, the universities, mathematics, physics, cosmology and astronomy, optics, medicine, natural history, magic, and more.

Lindberg, David C, and Robert S. Westman. *Reappraisals of the Scientific Revolution*. Cambridge: Cambridge University Press, 1990. A collection of essays by eminent scholars intended to re-evaluate common views of the development of sixteenth- and

seventeenth-century science. Generally at a high level, but most articles are quite accessible and are very useful for further developing points brought forth in the lectures.

Lindberg, David C, and Ronald L. Numbers. *God and Nature: Historical Essays on the Encounter between Christianity and Science*. Berkeley: University of California Press, 1986. Collection of essays on the relationship between science and religion from the Patristics to twentieth-century creationism.

Long, Pamela O. "Humanism and Science" in *Renaissance Humanism: Foundations, Forms, and Legacy*, ed. Albert Rabil, Jr. Philadelphia: University of Pennsylvania Press, 1988, vol. 3, pp. 486-512. Readable and erudite overview of the role of humanism in early modern science, analyzing the various scholarly views of the role of humanism in science.

. *Technology, Society, and Culture in Late Medieval and Renaissance Europe, 1300-1600*. Washington, D.C.: SHOT/AHA, 2000. An excellent, brief (77 pages), illustrated, and highly readable text on aspects of early modern technology—from mining and gunnery to textiles, agriculture, and sculpture. Part of a series of short monographs on technology (priced at just \$8!) available at www.theaha.org.

McEvoy, James. "The Metaphysics of Light in the Middle Ages", *Philosophical Studies* 26 (1979): 126-145. High-level text but important in terms of an introduction to a difficult but important feature of medieval thought—in natural philosophy and elsewhere.

Neugebauer, Otto. *The Exact Sciences in Antiquity*. New York: Dover, 1969. A classical work dealing with Babylonian, Egyptian, and Greek mathematical and astronomical texts. This book can be tough slogging, most useful for those with a good grasp of astronomy and mathematics to start with. Emphasizes scientific content over cultural context.

Newman, William R. "Technology and Alchemical Debate in the Middle Ages", *Isis* 80 (1989): 423-445. A fascinating article that argues for alchemy's bold (and modern-sounding) claims for the power of human artifice over nature. (Also in the Shank reader, below.)

North, John. *The History of Astronomy and Cosmology*. New York: Norton, 1995. An outstanding survey of the history of astronomy from prehistory to the modern era. Lucidly organized and written, exhaustive in coverage, and masterful in presentation, North's work has become a standard source. If you want one book to use as reading and reference in the history of astronomy, choose this one.

Osler, Margaret J. "How Mechanical Was the Mechanical Philosophy? Non-Epicurean Aspects of Gassendi's Philosophy of Nature", in *Late Medieval and Early Modern Corpuscular Matter Theories*, edited by Christoph Luthy, John Murdoch, and William Newman, pp. 423--439. Leiden: Brill, 2001. A very clear and interesting analysis of Gassendi's mechanical system and its "nonmechanical" elements.

---. *Rethinking the Scientific Revolution*. Cambridge: Cambridge University Press, 2000. A collection of essays dealing with various aspects of the current re-evaluation of the concept and content of the Scientific Revolution, beginning with a spirited debate between Westfall and Dobbs, scholars cited in various places throughout this course.

Plato. *Republic*. There are a huge number of translations of this important work available, many with commentaries of greater or lesser value. The most important section for historians of science is Book VII, which contains the "Parable of the Cave," a key exposition of Plato's ontology and epistemology.

Pliny. *Natural History*. New York: Penguin, 1991. Representative selection of some of the more entertaining sections of Pliny's encyclopedic work. If you want the whole thing, try the Loeb Classical Library edition.

Principe, Lawrence M. *The Aspiring Adept: Robert Boyle and His Alchemical Quest*. Princeton, NJ: Princeton University Press, 1998. Treatment of the previously oft-hidden alchemical preoccupations of Boyle; includes two provocative (and hitherto unpublished) texts by Boyle on alchemy.

Principe, Lawrence M., and William R. Newman. "Some Problems in the Historiography of Alchemy", pp. 385-434 in *Secrets of Nature: Astrology and Alchemy in Early Modern Europe*, edited by Anthony Grafton and William Newman, pp. 385--434. Cambridge, MA: MIT Press, 2001. Debunks four widespread popular misconceptions about the subject of alchemy and shows the origins of these misconceptions.

Ptolemy. *Tetrabiblos*, trans. Frank Egleston Robbins. Cambridge, MA: Harvard University Press, 1980. Part of the Loeb Classical Library series, presented with Greek and English on facing pages. This is the classical source for the astrological tradition and is surprisingly readable.

Ross, Sydney. *Nineteenth-Century Attitudes: Men of Science*, chapter 1: "Scientist: The Story of a Word". Dordrecht: Kluwer Academic Publishers, 1991. Amusing history of the coinage and slow acceptance of the word "scientist"-will greatly surprise most readers.

Sabra, A. I. "Greek Science in Islam," *History of Science* 25 (1987): 223-243. Thoughtful piece on the translation movement and the fate of Greek science in the Arabic world.

---. "Situating Arabic Science: Locality versus Essence", *Isis* 87 (1996): 654-670. Probes the reasons behind the Arabic embrace of Greek learning and briefly explores the cause of the decline of Arabic science, with a plea for more scholarly attention to be paid to this important and understudied area.

Shank, Michael H., ed. *The Scientific Enterprise in Antiquity and Middle Ages: Readings from Isis*. Chicago: University of Chicago Press, 1996. A collection of twenty-two articles from *Isis*, the journal of the History of Science Society. The volume makes a good "reader" for those interested in more advanced and detailed discussions of particular events, topics, or characters from antiquity and the Middle Ages. (See the similar reader volume by Dear, ed., above.)

Stahl, William Harris. *Roman Science: Origins, Development, and Influence to the Later Middle Ages*. Madison, WI: University of Wisconsin Press, 1962. There's not a great deal of material on Roman science available; this is the classic study.

Stroup, Alice. *A Company of Scientists: Botany, Patronage, and Community at the Seventeenth-Century Parisian Royal Academy of Sciences*. Berkeley, CA: University of California Press, 1990. An excellent view of this important scientific society during its early years of the seventeenth century. The first five chapters give a fine overview of the structure and founding of the Academie; the balance deals with more specific issues-particularly in botany and chemistry as illustrations of the society.

Theophilus. *On Divers Arts*, trans. John G. Hawthorne and Cyril Stanley Smith. New York: Dover, 1979. Want to know how to cast a bronze censer, build an organ, or

construct a stained-glass window starting with sand, ashes, and lead? Then this eleventh-century text from a monastic workshop is the book for you.

Thoren, Victor E. *The Lord of Uraniborg: A Biography of Tycho Brahe*. Cambridge: Cambridge University Press, 1990. Can be difficult to read at times, but the standard biography of the Great Dane.

Westfall, Richard S. *Never at Rest: A Biography of Isaac Newton*. Cambridge: Cambridge University Press, 1980. Most complete and up-to-date biography of Isaac Newton. This is quite a massive volume; for those not wishing to read the whole thing, there is an abridged version at about a third the length.

Westman, Robert S. "Three Responses to the Copernican Theory: Johannes Praetorius, Tycho Brahe, and Michael Maestlin", in *The Copernican Achievement*, edited by Robert S. Westman, pp. 285-345. Berkeley and Los Angeles: University of California Press, 1975. Important study of how Copernicus' work was interpreted and used in the sixteenth century.

---. "Proof, Poetics, and Patronage: Copernicus' Preface to *De revolutionibus*", in *Reappraisals of the Scientific Revolution*, edited by David C. Lindberg and Robert S. Westman, pp. 167-205. Cambridge: Cambridge University Press, 1990. Interesting study of the publication of *De revolutionibus* and Copernicus' humanism.

Wheelwright, Philip. *The Pre-Socratics*. Indianapolis, IN: Bobbs-Merrill, 1960. Emphasis here is given to the fragments of the Pre-Socratics themselves. The brief introductions to each author and his school are particularly useful. A better first book on this topic than Kirk and Raven, in my opinion.

Wilken, Robert L. *The Christians as the Romans Saw Them*. New Haven: Yale University Press, 1984. A book that "turns the tables" since the popular view of the Romans is often through Christian eyes; here, the (pagan) Romans get their turn. Interesting description of the development of early Christian theology as a response to learned pagan criticism.

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Lawrence Principe was an undergraduate at the University of Delaware, where he received a B.S. in Chemistry and a B.A. in Liberal Studies in 1983. During this time, he developed his interest in the history of science, particularly the history of alchemy and early chemistry. He then entered the graduate program in Chemistry at Indiana University, Bloomington, where he worked on the synthesis of natural products. Immediately upon completing the Ph.D. in Organic Chemistry (1988), he re-entered graduate school, this time in the History of Science at Johns Hopkins University, and earned a Ph.D. in that field in 1996.

Since 1989, Professor Principe has taught Organic Chemistry at Johns Hopkins University. In 1997, he earned an appointment in History of Science and began teaching there as well. Currently, he enjoys a split appointment as professor between the two departments, dividing his teaching equally between the two at both graduate and undergraduate levels. He also enjoys annoying safety inspectors by performing alchemical experiments in his office.

In 1999, Professor Principe was chosen as the Maryland Professor of the Year by the Carnegie Foundation, and in 1998, he was the recipient of the Templeton Foundation's award for courses dealing with science and religion. He has also won several teaching awards bestowed by Johns Hopkins.

Professor Principe's interests cover the history of science of the early modern and late medieval periods and focus particularly on the history of alchemy and chemistry. His first book was entitled *The Aspiring Adept: Robert Boyle and His Alchemical Quest* (1998), and he has since collaborated on a book on seventeenth-century laboratory practices (*Alchemy Tried in the Fire*) and on a study of the image of the alchemist in Netherlandish genre paintings (*Transmutations: Alchemy in Art*). He is currently at work on a long-term study of the chemists at the Parisian Royal Academy of Sciences around 1700.