History of Science 100

KNOWING THE WORLD: AN INTRODUCTION TO THE HISTORY OF SCIENCE

Fall 2009

Harvard Hall 201

Tuesday and Thursday, 11-12
with an additional required section meeting to be assigned

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There are two main ways of understanding what is meant by the word "science." One refers to a body of knowledge about the world; the other to methods of obtaining and securing that knowledge. This course deals with both these conceptions and treats them together. The world we come to know about is shaped by the means we use to know it, and those means of knowing are molded by what we think the world is.

This is a survey of the history of what we have come to know about the world and how we have come to know it. We take you from the "Scientific Revolution" of the seventeenth century to the present, and in doing so we have two aims. First, we'd like you to develop a historical sensibility about scientific knowledge and ways of knowing, and that means we want you to appreciate something of the "otherness" of past epochs-- past senses of what the world is and past ways of knowing it. For example, in the late seventeenth century Isaac Newton said that it was a legitimate part of "natural philosophy" to talk about God and His attributes, while at present it is widely regarded as wrong or nonsensical to mix science and religion. Also during the seventeenth century, polemical arguments had to be made in defense of systematic experimentation, and now experiment is right at the heart of what it means to be scientific. It has been said that "the past is a foreign country," and we want you to approach the scientific past as something other than a foreshadowing of what scientists now know.

Second, we'd also like you to appreciate some *similarities* between the distant past and our present circumstances. Certain questions-- if not the answers to them-- are as much alive today as they were centuries ago: What is the proper role of pre-existing authority in constructing our own knowledge? What is the best way of knowing nature-- by pure reason, by observation, by artificial experiment, by modeling, or by some combination of these? What is proper scientific knowledge *for*? Is it for satisfying the pure urge to understand, or has it got some essential material or moral function? What is the relationship between science and religion as ways of knowing the world? Is the place of human beings in the world just the same as that of any other natural entity or are we, in some sense, special? Can you have a science of human beings and human society, and, if so, is it just the same as a science of things?

In considering these questions, we emphasize three key themes throughout the course. One is the relation between science and utility: what is science *for* and how have sensibilities about the utilities of science changed over time? The second theme concerns the relationship between the human world and the natural world-- and the shifting place of God in our understandings of nature. What happens to natural knowledge once divine agency is excluded from our understanding of how nature works? How does this exclusion transform our understanding of ourselves, our place in nature, and our ability to manipulate or transform the world? Finally, we consider the ways in which science emerged over the course of the last few centuries as an inherently *global* practice. By this we mean both how science was shaped by global networks-- through the circulation of peoples, goods and ideas-- and how science itself came to have increasingly global applications, from botanical lore to atomic diplomacy to entrepreneurial science.

This course does not attempt to be definitive or exhaustive: this is not "all you need to know" about the history of science; it is not a celebration of great geniuses or theories. It is an attempt to pick out of the historical flow a handful of episodes that we judge to be particularly revealing, perspicuous, or pertinent. In place of definitiveness, we offer a set of sensibilities about the historical development of science, and about the relationships between science and society, that may change the way you think about both past and present and that you may wish to explore further in other courses.

For each section, we designate a combination of primary sources (writings coming from the historical period being considered) and secondary sources (what later historians have had to say about this period). Each type of reading is very important, but engagement with the primary sources-- strange as these may sometimes seem to you in their style, tone, and assumptions-- is vital. It's the very strangeness of these texts which we want you to appreciate, and, finally, to overcome.

READINGS:

--Two books available for purchase at the Harvard Coop (also on reserve in Lamont)—these are marked with an asterisk (*) in the syllabus:

> Stillman Drake, ed., *Discoveries and Opinions of Galileo* (Garden City, NY: Anchor Books, 1957).
>
> Steven Shapin, *The Scientific Revolution* (Chicago: University of Chicago Press, 1996).

--All other readings will be available in PDF form on the website under the appropriate week. One (and perhaps the cheapest) option would be to print these directly off the website. Alternatively, printed versions of all the readings will be available on reserve in Lamont for photocopying.

Unless otherwise indicated, readings should be completed *in advance* of your section meeting that week.

COURSE REQUIREMENTS:

Final grades will be calculated on the basis of the following requirements:

1. Section attendance, preparation, and participation **(15% of final grade)**.

2. Midterm examination (in class): Thursday, 15 October **(20% of final grade)**
   (Alternate date: Tuesday, 13 October-- with instructor's permission).

3. Three 5-7 page papers, due in class **(30% of final grade, 10% each)**. The tentative due-dates for these papers are 29 September, 12 November, and 3 December.

4. Final examination given during Final Examination Period **(35% of final grade)**.

NB: This course may be taken Pass/Fail with the permission of the instructor. However, *all* course requirements-- including section participation-- must be satisfactorily completed to merit a "Pass."

This course, when taken for a letter grade, meets the General Education requirement for Culture and Belief or the Core area requirement for Historical Study A. History of Science 100 fulfills the requirement that one of the eight General Education courses also engages substantially with Study of the Past.

COURSE WEBSITE:

The url for the course website is http://courses.fas.harvard.edu/0905. In addition to the syllabus and assignments, the website will have links each week to the readings, timelines, key images (if any), and PowerPoint slides (for some lectures). You are strongly encouraged to print out the primary source readings and bring them to section for discussion.

The website should be checked regularly as it includes course announcements, grading policies and procedures, and helpful online links.

Lectures are an integral part of this course; they do not simply summarize readings nor does web-based material substitute for attendance at lectures. You should expect to **take notes**.

COURSE MANNERS:

If you plan to bring a laptop to class to take notes, we ask you to use it *only* for that purpose. All other uses during class-time-- from checking email and Facebook to chasing up references on-line-- are discourteous, disruptive, and, ultimately, detrimental to your own learning experience.

UNIVERSITY POLICIES AND REGULATIONS:

We uphold University policies and regulations on the observation of religious holidays, sexual harassment, racial or ethnic discrimination, and assistance available to students with disability issues. Any students requiring special accommodation should talk to the Head TF as soon as possible. We also uphold University policy with respect to cases of plagiarism. Students should make themselves familiar with the respective University regulations and are encouraged to bring any questions or concerns to the attention of the teaching staff.

SYLLABUS:

Section 1 (9/3, 9/8) Introductions

The course starts with passages of "early modern" science, that is, with the period commonly designated as the "Scientific Revolution" of the seventeenth century. This is the moment which, in many accounts, "Made the Modern World," when "Modern Science" came into being and when "we" began to think in characteristically modern terms. There is something quite right about these stories: some very important changes in ways of knowing about the world and in what was known about the world occurred at or around this time. And these changes are rightly associated with the work of many of the individuals we will be reading about in the five weeks that follow: Galileo Galilei, Francis Bacon, René Descartes, Robert Boyle, Robert Hooke, Antoni van Leeuwenhoek, and Isaac Newton. But there is also something misleading about these stories: they are too simple, too neat, and too global. They make historical change seem like a light-switch that one can flip from "off" to "on"; they ignore much variation in what early modern thinkers knew and how they knew it; they conflate the views of a small number of thinkers with what a global "we" believed; and, most immediately, they reduce both the immense period before the "Scientific Revolution" and the few centuries that followed it to irrelevant footnotes. Historical change is not like that. So we start by talking about the leading themes and concerns of this course as it moves from the seventeenth century to the present. We introduce some general considerations about how one should think about science and its history and then we sketch characteristics of the scientific traditions inherited from ancient Greece and Rome which iconic figures of the "Scientific Revolution" saw themselves as rejecting.

Optional secondary reading:

G. E. R. Lloyd, "Aristotle," in idem, *Early Greek Science: Thales to Aristotle* (London: Chatto & Windus, 1970), pp. 99-124.

Section 2 (9/10, 9/15) Knowing about the Very Distant

In the Aristotelian philosophy of nature it was maintained that the heavens and the Earth belonged to different orders: they were made of different stuff and they obeyed different laws. This meant that the "world" understood by natural philosophy was not one but two, and that knowledge of how bodies behaved on or about ground level did not necessarily apply to how celestial bodies behaved. Yet a number of seventeenth-century thinkers challenged that separation between terrestrial and celestial principles and, in so doing, constituted the domain of natural philosophy as unitary. There was *one* natural world and *one* body of descriptive and explanatory principles accounting for it. But how did one go about securing knowledge of the heavens? Theory was one way; new scientific instruments such as the telescope were another. Both offered vast new intellectual possibilities and both were attended with intellectual problems. And what did one say about the authority of Holy Scripture in describing the natural world? Did observation and experiment trump the Bible? If not, how did the natural philosopher deal with the apparently differing accounts of nature were found in Scripture?

Required primary reading:

*Galileo Galilei, *Letter on Sunspots* (1613), in *Discoveries and Opinions of Galileo*, ed. Stillman Drake (Garden City, NY: Anchor Books, 1957), pp. 87-144.

*Galileo Galilei, *Letter to the Grand Duchess Christina* (1615), in *ibid*., pp. 145-216.

Required secondary reading:

*Steven Shapin, *The Scientific Revolution* (Chicago: University of Chicago Press, 1996), pp. 1- 64.

[You will be reading all of this little book. Pages broadly relevant to sections are indicated, but you should try to read the book as a whole just as soon as you are able to. Some sections of the book assigned here, for example, are relevant to the work of next week and that following.]

Section 3 (9/17, 9/22, 9/24) Knowing about the Very Small

We have now seen that there were problems associated with crediting instrumental observations of celestial bodies. Yet the existence and gross appearance of such bodies were everyday aspects of human experience: people knew they existed and were familiar with their apparent motions. Things were different with the very small. People knew that there were very small things in the world, but before the seventeenth century they did not know that there were things invisible to the unassisted human senses. Were there creatures smaller than the unaided eye could see? Were the structures of visible objects the same as those that might be beyond unaided human vision? The invention of the microscope, like that of the telescope, posed problems for crediting observations of the very small, while it bore a seminal relationship to one of the central concepts of the new natural philosophy emerging in the seventeenth century-- the idea that nature, at its ultimate level, was made up of mechanical structures and that it behaved mechanically.

During the course of the seventeenth century, a number of practitioners began to assert that the ultimate structure of reality was *micro-mechanical*– that is, the basic building blocks of matter, and the ways in which matter produced its visible effects, could be understood in the same way that one understood how machines worked. Here we explore the implications of that mechanical view for what counted as a scientific explanation and for how one might go about securing knowledge of the micro-mechanical world. We talk about relationships between *experimental* ways of knowing and *mechanical* views of what nature was like. How did you do experiments? Why did you do them? And what did you learn about the world from doing them?

Required primary reading:

Robert Hooke, *Micrographia* (London, 1665), selections: preface, pp. 1-5, 112-116, 153-154, 171-172, 175-180, 210-217, 242-246.

*Galileo Galilei, *The Assayer* (1623), in Drake, ed., *Discoveries and Opinions*, pp. 229-280.

René Descartes, *Treatise on Man*, in Descartes, *The World and Other Writings*, ed. and trans. Stephen Gaukroger (Cambridge: Cambridge University Press, 1998; orig. publ. 1661), pp. 99-107, 116-119.

Robert Boyle, *New Experiments Physico-Mechanical* (1660), in Boyle, *Works*, ed. Thomas Birch, 6 vols. (London, 1772), Vol. I, pp. 1-117 (selections: pp. 5-10, 15-19, 33-39, 69-70).

Required secondary reading:

*Steven Shapin, *The Scientific Revolution* (Chicago: University of Chicago Press, 1996), pp. 65-117.

Section 4 (9/29, 10/1) Knowing the Whole World from a Particular Place in It

One condition of scientific knowledge becoming *global* or *universal* is that it spreads from its local point of origin. Science and scientists are located in physical space, but they hope to produce knowledge that transcends particularities of place. This section considers two aspects of the problem of globalized knowledge. The first concerns the institutional place of science and how this was changing during the course of the seventeenth century. What kind of place, for example, was the new Royal Society of London? Who were the members? What did they want reformed scientific knowledge to achieve? And how did they think about the goals of science and the social forms in which science was to be produced? Here we consider the Royal Society both as a collegial and peaceable sort of place and as a site in which *useful knowledge* was produced, knowledge that might flow out into the world and transform humankind's ability to control and manipulate nature. Second, we look at aspects of how people staying at home, for example in London or Amsterdam, could come to know about distant reaches of the world, say the Spice Islands of what is now Indonesia. Most natural phenomena that a community might come to know about could only be witnessed by a few, since they were distant in space or time. How did you collect, collate, sort, and evaluate reports coming from distant parts or times? Such problems became more pressing as Europeans began to act at a distance, on a global scale-- conducting commerce and projecting power throughout the world.

<u>Required primary reading</u>:

Thomas Sprat, *The History of the Royal Society of London, For the Improvement of Natural Knowledge* (London, 1667), pp. 15-21, 25-28, 32-34, 46-115,155-172, 378-397.

[While most of the Sprat reading is for the 9/29 lecture, pp. 155-172 will be discussed in lecture on 10/1]

James Bontius, *An Account of the Diseases, Natural History, and Medicines of the East Indies* (London, 1769; orig. comp. 1629), pp. vii-ix, 107-158.

<u>Required secondary reading</u>:

*Steven Shapin, *The Scientific Revolution* (Chicago: University of Chicago Press, 1996), pp. 119-165.

Section 5 (10/6, 10/8) Newton: Universal Knowledge and "Making the Modern World"

For many historians, the work of Isaac Newton represents both the crowning achievement of the Scientific Revolution and the moment at which the world, and our ways of knowing it, became recognizably "modern." Many late seventeenth- and early eighteenth-century thinkers agreed: Newton was the greatest scientific genius the world had ever seen and he had revealed the fundamental laws by which nature worked. Yet this picture needs to be qualified: first, there was much of the "ancient" about this great "modern": Newton devoted an enormous amount of his energies to alchemy and Biblical chronology; second, his great *Mathematical Principles of Natural Philosophy* represents a contentious and unstable bringing together of mathematical and philosophical ways of knowing that were problematic in the early modern period and that, to some extent, remain so today. The reading for this section is not vast, but it is somewhat demanding. You should also review some of the earlier reading in *The Scientific Revolution* that deals with Newton.

Required primary reading:

Isaac Newton, *The Mathematical Principles of Natural Philosophy*, trans. Andrew Motte, 2 vols. (London, 1729): The Laws of Motion, vol. I, pp. 19-21; The General Scholium, vol. II, pp. 387-393.

Isaac Newton, *Opticks*, 4th ed. (London, 1730), Query 31, pp. 350-382.

Required secondary reading:

John Maynard Keynes, "Newton, the Man," in *The Royal Society, Newton Tercentenary Celebrations, 15-19 July 1946* (Cambridge: Cambridge University Press, 1947), pp. 27-34.

John Brooke, "The God of Isaac Newton," in *Let Newton Be! A New Perspective of His Life and Works*, eds John Fauvel, Raymond Flood, Michael Shortland, and Robin Wilson (Oxford: Oxford University Press, 1988), pp. 168-183.

Review Session (10/13)

There is no assigned reading for this session. It reviews our work so far, summarizing major themes and reminding you of sensibilities and arguments running through lectures and readings.

MID-TERM EXAMINATION (10/15)

Section 6 (10/20, 10/22) Knowing and Ordering

By the eighteenth century, new, powerful, and robust ways of knowing the world had been devised. The intellectual and institutional techniques of producing and circulating universal knowledge had largely been put in place, substantially uniting the world-wide scientific enterprise and ensuring that scientists were, by and large, on the same page in the Book of Nature. In the period known as the Enlightenment (ca. 1720s to 1780s), practitioners continued to be occupied with questions about how such global knowledge could be further secured and how knowledge of human beings and nature related to political and social change. This section examines two sets of practices characteristic of Enlightenment science, both of which had to do with ordering and spreading new (and old) knowledge. On the one hand, the empires of knowledge and power that Europeans had forged while traveling and conquering the globe confronted them with nature's teeming diversity, notably in its living things, a diversity which created practical needs for its ordering and classification into taxonomies. These taxonomies were subject to heated debate, as they were attempts to understand both the nature of things and the interrelationships between things, man, and God. We will read and discuss texts and taxonomies from the key natural historians of the eighteenth century, the Swede Carl Linnaeus and the Frenchman Georges-Louis Buffon. On the other hand, practitioners also addressed knowledge about human beings as social and economic actors, with a notable interest in the utilities of natural and technological knowledge. They aimed to collect and arrange artisanal and trade knowledge in encyclopedias, making this knowledge newly accessible to a supposedly universal public sphere. We read the introduction to the largest and most ambitious encyclopedic project of the French Enlightenment. How do the encyclopedic and taxonomic efforts of the eighteenth century appear in relation to practices used nowadays to capture and spread knowledge about the diversity of the natural, social, and cultural worlds, for example, Wikipedia or Google Books?

Required primary reading:

Carolus Linnaeus, *Systema Naturae* (10th ed, 1758), in *Dutch Classics in the History of Science*, vol. 8 (Nieuwkoop, the Netherlands: B. de Graaf, 1964), pp. 17-30.

Georges-Louis Leclerc, Comte de Buffon, "Initial Discourse" to *Histoire Naturelle* (1749), trans. John Lyon, in *From Natural History to the History of Nature: Readings from Buffon and His Critics*, eds John Lyon and Phillip R. Sloan (Notre Dame: University of Notre Dame Press, 1981), pp. 97-128.

Jean L. R. D'Alembert, *Preliminary Discourse to the Encyclopedia of Diderot*, trans. Richard Schwab (Indianapolis: Bobbs-Merrill 1963), pp. 3-14.

Required secondary reading:

Robert Darnton, "Google & the Future of Books," *The New York Review of Books*, 56, no. 2 (12 February 2009): http://www.nybooks.com/articles/22281

Dorinda Outram, *The Enlightenment* (Cambridge: Cambridge University Press, 1995), pp. 47-79.

Section 7 (10/27, 10/29) Knowing Our Place in Nature

Charles Darwin's theory of evolution by natural selection had a shattering effect on existing understandings of human beings' place in nature and on the relations between scientific knowledge and religious doctrine. After Darwin's *On the Origin of Species* (1859), nothing was ever the same. Our task in this section is to understand not just what Darwin's theory was but why it counted as such a shock to the cultural system inherited from past centuries. First, we need to revisit the body of belief known as "natural theology," seeking to appreciate how it bound together science and religion, how, indeed, it inscribed theological truths right at the heart of natural scientific explanation. William Paley's text *Natural Theology* (1802) was the greatest and most influential exposition of the so-called "argument from design," proving the existence and attributes of God from the evidence of a designed natural world. As an undergraduate at Cambridge, Darwin read this text, and, like most of his contemporaries, was struck by its intellectual power. When he embarked on his great voyage on *The Beagle* in 1831, Darwin was almost wholly convinced by Paley's argument. But several years after he returned from that voyage, he was beginning to think that it might be fundamentally wrong, and that both the Christian belief in the fixity of species and the inference of a creative intelligence from the evidence of design in nature might be unjustified. We read key sections of *The Origin* and Janet Browne's elegant historical account of the formation of Darwin's theory of natural selection.

Required primary reading:

William Paley, *Natural Theology: or, Evidence of the Existence and Attributes of the Deity, Collected from the Appearances of Nature* (Oxford: Oxford University Press, 2006; orig. publ. 1802), pp. 7-31 (chapters 1-3).

Charles Darwin, *The Origin of Species* (London: John Murray, 1859), Introduction (pp. 1-6), extracts from Chapter 1 (pp. 7-8, 10-11, 12-14, 23-24, 29-33, 34-36, 43), Chapter 4 (pp. 80-130), and extracts from Chapter 14 (pp. 459-460, 466-471, 480-482, 484-490).

Required secondary reading:

Janet Browne, *Darwin's Origin of Species: A Biography* (London: Atlantic Press, 2006), pp. 58-117.

Section 8 (11/3, 11/5) Knowing about Knowing

Darwin's view of the organic world and how it developed was *naturalistic*. That is to say, all the causes involved in giving a scientific account of the form of species and the mode of species change were not supernatural but natural. There was no need to invoke God's special creative powers or divine intervention in the course of nature; there was no necessity to infer a Higher Intelligence from the evidence of the adaptation of organic structure to function. Partly inspired by Darwin and partly responding to general cultural currents, expert scientific thought began to be closely identified with naturalism, and the name *Scientific Naturalism* was given to a body of thought explicitly and sometimes aggressively opposed to religious invocation of supernaturalism forces in explaining natural phenomena. Unlike the situation in the seventeenth century, the idea of science became identified with the idea of purely natural causes. The recommendation, and the criticism, of Scientific Naturalism was a highly polemical affair. Here we look at one of the most emotionally charged moments in the career of late nineteenth-century Scientific Naturalism, the so-called Prayer Gauge Debate, in which the efficacy of prayer was taken as claim for the existence and power of supernatural forces in nature and in which it was suggested that such efficacy be subjected to a scientific test.

Scientific Naturalism was one expression of the emerging notion that science was and should be, in its very nature, *value-free knowledge*. Since the natural world-- the object of scientific knowledge-- was the playground of purely natural forces, doing science was *not* reading God's Book of Nature-- as was believed in the seventeenth century. Science now had no moral lessons for humankind, and the scientist was no longer to occupy the same cultural terrain as the priest. One of the most eloquent and influential expressions of the *amorality* of modern scientific knowledge and the occupants of the modern scientific role came from the German sociologist Max Weber (1864-1920), and his lecture on "Science as a Vocation" (1918) was *both* a comment on the institutional conditions of the scientific role and a warning to scientists not to take on the role of moralist.

Required primary reading:

John Tyndall, Francis Galton, et al., *The Prayer-Gauge Debate* (Boston: Congregational Publishing Society, 1876), pp. 1-19, 85-106, 135-144).

Max Weber, "Science as a Vocation," in *From Max Weber: Essays in Sociology*, trans. and ed. H. H. Gerth and C. Wright Mills (London: Routledge, 1991; art. orig. publ. 1919, from a speech in 1918), pp. 129-156.

Required secondary reading:

Robert Bruce Mullin, "Science, Miracles, and the Prayer Gauge Debate," in *When Science & Christianity Meet*, eds David C. Lindberg and Ronald L. Numbers (Chicago: University of Chicago Press, 2003), pp. 203-224.

Section 9 (11/10, 11/12) Knowing about Ourselves

Darwinian evolution seemed to make it very clear that human beings had emerged out of lower life forms through wholly natural processes. But did this naturalistic understanding apply also to the human *mind*-- that is, to the consciousness that animates each and every one of us, that falls in love, that wonders about the universe, that fears death, and longs for immortality? Was mind a part of nature too? And, if so, what would it mean to investigate it using the methods of natural science? Here we look at two projects from the late nineteenth and early twentieth centuries that attempted, in different ways, to respond to this question. The first was an effort to map the functions of the human mind onto the workings of the human brain; and the second sought to illuminate deeper laws governing human motivation and also human metal illness through study of an invisible entity that came to be called "the unconscious." Shaping the first project were at least two big ideas: *cerebral localization* and *reflex theory*. Shaping the second project were two further big ideas: our conscious mind does not run the show (the unconscious does), and the unconscious is a primitive, powerful entity driven by instinct, especially of sexual and (in later versions) aggressive nature. We may think of these projects as quite different, and in many ways they were. However, they were both products of the assertive naturalizing impulse of the late nineteenth century that was no longer going to cede any special status to human beings and their minds. They were both informed by the new evolutionary thinking of the time. And both raised radical and often disturbing larger questions about the fate of the soul, the nature of free will, and the concept of human rationality.

<u>Required primary reading</u>:

Thomas Henry Huxley, "On the Hypothesis that Animals are Automata and Its History [1874]," in idem, *Collected Essays, Vol. I: Method & Results* (New York: Greenwood Press, 1968 [collection orig. publ. 1917]), pp. 199-250.

Joseph Breuer, "Anna O." and Sigmund Freud, "Katharina," from *Studies on Hysteria* [1895], in *The Freud Reader*, ed. Peter Gay (New York: W.W. Norton & Company, 1995 [1989]), pp. 60-85.

Sigmund Freud, excerpts from "Civilization and its Discontents [1930]," in *The Freud Reader*, ed. Peter Gay (New York: W.W. Norton & Company, 1995), pp. 722-772.

<u>Required secondary reading</u>:

Daphne de Marneffe, "Looking and Listening: The Construction of Clinical Knowledge in Charcot and Freud," *Signs* 17 (1991), 91-112.

Anne Harrington, "The Brain and the Behavioral Sciences," in *The Cambridge History of Science, Vol. 6: The Modern Biological and Earth Sciences*, eds Peter J. Bowler and John V. Pickstone (Cambridge: Cambridge University Press, 2009), pp. 504-523.

Section 10 (11/17, 11/19) Science and War

Science has always flourished in times of war and technically knowledgeable people have always been enlisted to enhance and project State military power. The pattern goes back at least to Greek Antiquity and we have noted the associations between natural knowledge and State power in the seventeenth and eighteenth centuries. Nevertheless, the reflective recognition that scientific knowledge should be encouraged because of its specific contributions to military power, and, especially, that science might bring into being new kinds of strategic power substantially begins in the twentieth century. Largely because of the role of the chemistry of explosives and especially of poison gas, World War I has been called "the chemists' war," but reference to the Second World War as "the physicists' war" is much better known, owing to the development of radar and the atomic bomb. The Second World War reinforced the authority of scientific and technical expertise and transformed the relation between science, politics, and the State. In 1961, the Farewell Address of President Eisenhower identified what the old general condemned as the dangers of "the Military-Industrial Complex," in which, as he saw it, the joined interests of big industrial contractors and the Pentagon subverted democratic decision-making and corrupted the integrity of science. Whether or not one shares Eisenhower's sensibilities, there is no doubt that one cannot understand the development of science and technology in the second part of the twentieth century without giving attention to military needs and military funding.

<u>Required primary reading</u>:

Dwight D. Eisenhower, "Farewell Radio and Television Address to the American People [17 January 1961]," in *The Military-Industrial Complex,* ed. Carroll W. Pursell, Jr. (New York: Harper and Row, 1972), pp. 204-208.

Alvin M. Weinberg, "Impact of Large-Scale Science on the United States," *Science* 134, no. 3473 (21 July 1961), 161-164.

<u>Required secondary reading</u>:

Daniel Charles, *Between Genius and Genocide: The Tragedy of Fritz Haber, Father of Chemical Warfare* (London: Jonathan Cape, 2005), pp. 73-95, 141-185.

Thomas Parke Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm, 1870-1970* (New York: Viking, 1989), pp. 353-443, 503-510.

Section 11 (11/24, 12/1) Science and Utility in Modern Times

[NOTE: 11/26 is Thanksgiving, so this section spreads over two weeks.]

Previous sections of this course have addressed assertions that scientific knowledge would ultimately have useful material outcomes. It was largely on the basis of these claims that practitioners argued that scientific inquiry should have a legitimate claim on State support. The State might not care to support "knowledge for its own sake," but it was presumed to have vital interests in knowledge that could enhance military power and produce the technologies fuelling economic growth. For a very long time there was great skepticism about such claims, but by the late nineteenth and early twentieth centuries it was increasingly accepted that, as Bacon once said, "knowledge is power." We look, first, at the late nineteenth- and early twentieth-century development of science in industry, and then at the institutionalization in the immediate post-World War II period of the idea that the State ought to support all sorts of scientific research because of its ultimate utility.

Required primary reading:

C. E. Kenneth Mees, “The Organization of Industrial Scientific Research,” *Science* 43, no. 1118 (2 June 1916), 763-773.

Herbert Hoover, “The Vital Need for Greater Financial Support to Pure-Science Research,” *Mechanical Engineering* 48 (January, 1926), 6-7.

Vannevar Bush, *Science-- The Endless Frontier: A Report to the President on a Program for Postwar Scientific Research* (Washington, DC: National Science Foundation, 1945), pp. 1-40.

I. Bernard Cohen, *Science*, *Servant of Man: A Layman’s Primer for the Age of Science* (Boston: Little, Brown, 1948), pp. 3-16, 67-84, 176-195.

Required secondary reading:

David A. Hounshell, “The Evolution of Industrial Research in the United States,” in *Engines of Innovation: U.S. Industrial Research at the End of an Era*, eds Richard S. Rosenbloom and William J. Spencer (Cambridge, MA: Harvard University Press, 1996), pp. 13-85.

Section 12 (12/3) Course Review

We use this session to review leading themes of the course. There is no required reading.