HPS 154
What is Science? Explaining Nature from Pythagoras to Popper
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SYLLABUS
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How do scientists know what they know—or claim to know? It's an important question, not just for scientists themselves, but for any of us who drive on bridges without fear, subject ourselves to doctor's prescriptions, or must decide whether grade-school teachers should teach evolution or intelligent design. Science and its products pervade our personal, political, institutional, and cultural lives. We need to know where it comes from and whether it is reliable.

How do scientists know what they know? Well, we might say, they use the "scientific method." But, alas, there are now and have long been great debates over exactly what a proper scientific method is. Scientific debates often come down to disagreements over method, and the results of the debates can be deadly. Millions of people have died from crackpot science, teachers have been condemned for teaching science developed with unauthorized methods, and scientists have been jailed and put to death for using the wrong method.

The science that results from different methods can be vastly different, and great advances—and great declines—in science often result from a change in method. Reciprocally, reactions to particular scientific developments can greatly influence the methods other scientists use. To learn about how scientists know what they know, we will look at this interplay between science and scientific methods from Ancient Greece to modern times.

We will examine debates that began in ancient Greece about the nature of certainty. We will face an age-old question whether scientists must be content to accurately describe what they observe or can also be justified in claiming to know how things really are. We will examine conflicts between independent judgment and religious dogma. We will meet Pythagoras, Euclid, Plato, Aristotle, Galileo, Descartes, Newton, Darwin, Heisenberg, and others. We will meet great scientists, great philosophers of method, and some who were both.

Primary sources will be the core of our study. Secondary courses will supplement. That is, for example, we will rely most heavily on our own reading of Aristotle or Galileo or Darwin than on what some modern commentator says about them. Though many of the works we'll read were written in another language, we will use English translations. Nonetheless, we will occasionally face the problems that arise with translations. If you happen to know another language (especially Latin or a Romance language) you may get the chance to use it a little.

When we finish, you will have an understanding of the different ways scientists have tried to explain nature and the implications of those attempts—both for them and for us.

Course grade
Your course grade will be based as follows on class participation, three papers, each 900-1100 words, and one short quiz given during the final class.

30%	Class participation
20%	Paper #1
20%	Paper #2
25%	Paper #3 (You should be getting better at this, so I'll count the final one a bit more.)
5%	Quiz on last day of class

There is no final exam. If you are unhappy with the grade on one of your papers, you may replace it with a fourth, due on the last day of exam week. You could even skip one of the first three papers and turn in this last one instead. I do not recommend this.

The topics for the papers will be mutually agreed upon. Throughout our classroom discussions, I will note good paper topics as they come up. I will also say more on how to select a topic and on how to write the papers.

Grades
I have no reservation about giving all As. I have no reservation about giving Bs, Cs, and Ds. In a small seminar class, as this one is, I am fully capable of finding enough time and energy to help any student excel who wants to. The concepts in this course are not difficult. Wide and deep prior knowledge is not required. The reading can be heavy and I demand critical thinking and clear presentation, but any Stanford student interested in history, philosophy, and/or science, willing to budget the time, and able to come to every class prepared can do well in this course.

Class participation
When I say that 30% of your grade is for class participation, I'm serious. I do not mean class attendance, I mean class participation. If you write all A papers but never engage in the class discussion, you could get a C for the course. Moreover, when I say class participation, I mean quality, not quantity. You do not need to be a pushy big-mouth. You can be reserved and naturally quiet. But you need to have read and thought about the assignments and be ready to engage in scholarly discussion with me and your classmates. I will make sure everyone has the opportunity to do so.

Workload and Pace
The reading can be extensive, though I'll give you hints along the way on how best to manage it. Not all works need to be read with equal care, so don't panic when you see the reading list. There are three papers, but they are not long and do not require extensive outside research. The final quiz is easy.

The workload will ramp up quickly and stay moderate to heavy for several weeks. Weeks 3 and 4 will be particularly busy (though also two of the most fun). The good news is that if you plan well and keep the pace, the workload will tail off significantly at the end. Given that there is no final exam and that the short quiz on the final day is easy, if you write three good papers, you'll be through all the hard work around Thanksgiving, in time to dedicate your end-of-quarter energies to other courses.

Plagiarism
Until I had a student turn in a paper that was copied nearly verbatim from an old journal article, I never thought I'd see a case of plagiarism at Stanford University. But now that I have, let all be forewarned. Some professors prefer to handle cases of plagiarism themselves, exercising their own discretion, and working the matter out with the student one on one. I don't. I prefer to fully utilize the procedures administered by Stanford's Office of Judicial Affairs. It's tremendously fair. It eliminates any arbitrariness by the professor, and it places decision-making authority in the hands of a panel composed primarily of fellow students. And therein lies the warning: In cases of honest ignorance, there is nothing to fear, but in unambiguous and blatantly intentional cases of plagiarism, a panel of students judging other students can be flat-out merciless.

For info on plagiarism, see www.stanford.edu/dept/vpsa/judicialaffairs/students/ plagiarism.sources.htm. For sample cases, see http://www.stanford.edu/dept/vpsa/judicialaffairs/ judicialprocess/samplecases.htm. (Note the frequency of the phrase "one-quarter suspension.") For any questions, ask me.

Required Texts

We have a lot of material to read, but I've tried to keep costs down with on-line resources, public domain texts, and course reader excerpts. You'll need the following.

- *HPS 154 Course Reader* from the bookstore.
- Charles Freeman, *The Closing the Western Mind*. We only need 23 pages of this, but it's not available in excerpts, so you'll have to borrow or buy the whole book. Fortunately, because it's very popular right now, you'll be able to find it cheap. You can find used copies online for under $10.
- Isaac Newton, *Principia.* The now standard scholarly translation is by Cohen and Whitman, but it costs over $40 and has much we won't need. The only other full English translation was made by Andrew Motte in 1729 and revised by Florian Cajori in 1934. It has problems, but for us, it will do. You can get it in a cheap edition in the Great Minds Series published by Prometheus Books. Pages not in the Motte/Cajori translation that we need are in the *HPS 154 Course Reader*.
- Charles Darwin*, On the Origin of Species* (1859). There are many editions and printings of this, including some online (e.g., darwin-online.org.uk). Get the first, 1859, edition.
- Karl Popper, *The Logic of Scientific Discovery,* (Routledge, 2002). This edition, the second English edition, has been reprinted frequently since 1967. Any used copy after that is fine, but since used copies cost $10-$15 and you can get new ones for $14.25 at Amazon, you might as well buy a new one.
- *Faraday's Experimental Researches in Electricity: The First Series*, edited and annotated by Howard J. Fisher (Green Cat Books/Green Lion Press, 2004.) This is the thin, 84-page 2004 book for $8.95, not the 619-page 2001 book with a similar title for $35.

Finally

This is the first time I've taught this course, but I have wanted to for a long time. If you have an interest in any two of science, philosophy, and history and a background in any one, you should learn a lot and have a great time. I myself expect to do both.

And finally, finally.

I consider the comments about me and my courses at www.ratemyprofessors.com to be fair and accurate. I hope by the end of this one, you do too.

Course Reader

Week 2

- Aristotle. *A New Aristotle Reader*. Edited by J. L. Ackrill. Princeton University Press, 1987. *On the Parts of Animals.* Translated by James G. Lennox. Oxford University Press, 2001. *History of Animals.* Translated by Richard Creswell. Henry G. Bohn, 1862.
    - *Meteorology,* Ackrill, 158.
    - *Physics,* Ackrill*,* 93–100, 105–109.
    - *Parts of Animals,* Lennox, 1–8, 13–15.
    - *On the Heavens,* Ackrill, 132–42.
    - *History of Animals,* Cresswell, 39.
    - *Parts of Animals,* Lennox, 52–53.
- David Lindberg. "The Mathematical Sciences in Antiquity." *The Beginnings of Western Science.* The University of Chicago Press, 1992. 89–105, 375–377.
- Pierre Duhem. *To Save the Phenomena.* 1908. Translated by Edmond Doland and Chaninah Maschler. University of Chicago Press, 1969. 5–11.

Week 3

- Edward Grant. "The reception and impact of Aristotelian learning and the reaction of the Church and its theologians." *The Foundations of Modern Science in the Middle Ages*. University of Chicago Press, 1996. 70–85.
- William of Ockham. "Do the elements remain in a mixed thing?" *Quodlibetal Questions.* Third Quodlibetal, Question 5, 185–89.
- Bernardino Telesio, Prooemium to book 1 of *De Rerum Natura*. Translated by John P. McCaskey and

Week 4

- *The Galileo Affair*, "Cardinal Bellarmine to Foscarini, April 12, 1615," pp. 67–69, 333.
- Richard J. Blackwell, *Galileo, Bellarmine, and the Bible,* "Bellarmine's Biblical Cosmology," pp. 40–45; or (if I can get reprint permission) *Louvian Lectures of Bellarmine*, ed. Ugi Baldini and George V. Coyne, 8–22 (even) ; in *HPS 154 Course Reader.*
- *The Galileo Affair*, "Galileo to Castelli (21 December 1613)," pp. 49–54, 330.
- *Dialogues Concerning Two New Sciences,* on equal speed of descent regardless of weight and on the inclined-plane experiment, pp. 65–75, 153–71 in Wall & Emerson, 2000 edition.
- Francis Bacon, *Sylva Sylvarum*, p. 1.
- John P. McCaskey, "Outline of Rene Descartes, *Principia philosophiae* ."

Week 5

- Isaac Newton, "The Unpublished Preface," *The Principia*, Cohen and Whitman, eds., pp. 49–54.
- Roger Cotes, "Editor's Preface to Second edition," *The Principia*, Cohen and Whitman, eds., pp. 385-399.

Week 6

- Richard Whately, *Elements of Logic*, "Of Induction," bk. IV, ch. 1, pp. 255–66 in the London 1848 edition.
- John McCaskey, "William Whewell (1794–1866)"

Week 1 Sept 26 — **Mathematics: Pursuing Certainty by Deduction**

Handout:

- Aristotle on Pythagoras, *Metaphysics* 1.5, 985b23–986a13.
- Plato on the ultimate constituents of creation, *Timaeus*, 52d–53d, 89c.
- Euclid's proof that the angles of a triangle add to 180°, *Elements*, bk. 1, prop. 32.

Week 2 Oct 3 — **Aristotelian Natural Philosophy: Pursuing Certainty by Induction**

- Selections from Aristotle, all in *HPS 154 Course Reader.*
  - Meteorology I.1
  - Physics II.1, 2, 3, 7, 8
  - Parts of Animals I.1, 5
  - On the Heavens I.2, 9, 10, 12; II.12; III.6
  - History of Animals II.15 (labeled chapter XI in Cresswell's edition)
  - Parts of Animals III.3
- James G. Lennox, "Aristotle's Biology," *Stanford Encyclopedia of Philosophy.* http://plato.stanford.edu/entries/aristotle-biology.

Physics and Astronomy: Realism vs. Instrumentalism

- David Lindberg, "The Mathematical Sciences in Antiquity," *The Beginnings of Western Science,* pp. 89–105, 375–377, in *HPS 154 Course Reader*.
- Pierre Duhem, *To Save the Phenomena,* pp. 5–11, in *HPS 154 Course Reader.*

Week 3 Oct 10 — **Canonical Science: Finding Certainty in Authority**

- Charles Freeman, "'But what I wish, that must be the canon,'" *The Closing of the Western Mind*, ch. 12, pp. 178–201.
- Edward Grant, "The reception and impact of Aristotelian learning and the reaction of the Church and its theologians," *The Foundations of Modern Science in the Middle Ages*, ch 5, pp. 70–85, in *HPS 154 Course Reader.*
- William of Ockham, "Do the elements remain in a mixed thing?" *Quodlibetal Questions,* Third Quodlibetal, Question 5, pp. 185–89, in *HPS 154 Course Reader.*

The 16th-Century Renaissance: The Role of Personally Verifiable Observation

- Call for a new method: Bernardino Telesio, Prooemium to book 1 of *De Rerum Natura*, in *HPS 154 Course Reader.*
- The 1540s were a remarkable time in the history of science. Books of tremendous importance were published in about a half-dozen separate fields. Each student will pick a book, track it down in Stanford's rare book collection, read selections from a modern translation if necessary, and then be prepared to discuss what was found. Authors include Copernicus, Fuchs, Vesalius and Agricola. (Maybe Leonardo, too, though he was a little earlier.)

FIRST PAPER DUE beginning of class October 17.

Week 4 Oct 17 **The 17th-Century Methodological Debate: Authority, Experimentation, Induction, and Deduction**

The early seventeenth century witnessed several contentious debates over what was and was not the proper way to study nature. An author could have his books banned over this or even get himself burned at the stake. Galileo was forced to recant some of his scientific beliefs. Philosophers, scientists, politicians, and the pope all weighed in. We'll explore four views of science, those of Cardinal Bellarmine, Galileo, Francis Bacon, and Rene Descartes, and scientific works based on each.

- Bellarmine's scientific method: "Cardinal Bellarmine to Foscarini, April 12, 1615," in *HPS 154 Course Reader.*
- Bellarmine's science: Richard J. Blackwell, *Galileo, Bellarmine, and the Bible,* "Bellarmine's Biblical Cosmology," pp. 40–45; or (if I can get reprint permission) *Louvian Lectures of Bellarmine*, ed. Ugi Baldini and George V. Coyne, 8–22 (even) ; in *HPS 154 Course Reader.*

- Galileo's scientific method: "Galileo to Castelli (21 December 1613)," in *HPS 154 Course Reader.*
- Galileo's science: Selections from Galileo, *Dialogues Concerning Two New Sciences,* on equal speed of descent regardless of weight and on the inclined-plane experiment, pp. 65–75, 153–71 in Wall & Emerson, 2000 edition, in *HPS 154 Course Reader.*

- Bacon's scientific method: Francis Bacon, *Novum Organum*. "Proemium"; the "Plan of the Work" through the description of the second part of the work (about six pages); Book 1, Aphorisms 1–38.
- Bacon's science: *Novum Organum,* Book 2, Aphorisms 10–20 (you can skim most of this, but slow down to see what the three tables are, and pay attention to the beginning and end of Aphorism 20); *Sylva Sylvarum*, p. 1 in *HPS 154 Course Reader*;

- Outline of Rene Descartes, *Principia philosophiae* in *HPS 154 Course Reader*. There is no reason to read all of this book, but it is important to know its high-level outline and to get a sense of its scope. This chart will help. As you read through, as instructed below, see if you can figure out what the three shaded parts indicate.
- Descartes' scientific method: *Principia philosophiae*, Part 1, on course web site. Read the first few paragraphs slowly; then go quickly, reading the headings and just enough of the paragraphs to get a sense of Descartes' style of arguing; slow down at and carefully read paragraph 24; flip through the rest, slowing down to read paragraphs 30, 45, 75, 76.
- Descartes' science: Selections from *Principia philosophiae*, Parts 2, 3, and 4. Most is in PrinciplesOfPhilosophy.pdf on course web site; some is at www.princeton.edu/~hos/mike/texts/descartes/desc-mot.html. Read part 2, paragraph 1; then go quickly, reading the headings and just enough of the paragraphs to get a sense of Descartes' style of arguing; notice paragraph 11 (does this mean something is the same as nothing?); skim forward into the laws of motion. Switch over the Princeton web site. Again, keep skimming, but slow down and read paragraphs 46 through 52 (i.e., rules 1 through 7). Are these rules true? Just flip quickly through the rest of the book (in the pdf file), slowing down only to read part 4, paragraphs 199 and 207.

Week 5 **Isaac Newton**

Oct 24 The name, method, and science of Isaac Newton dominated the following two centuries and still permeate modern thought.

- Read the following, in this order:
  - Preface to Book 3, p. 319 in Great Minds edition.
  - The unpublished preface, pp. 49–54 in Cohen and Whitman, in *HPS 154 Course Reader*.
  - Editor's preface to 2nd edition, pp. 385-399 in Cohen and Whitman, in *HPS 154 Course Reader*.
  - Author's preface to 1st edition, pp. 3–5 in Great Minds edition.
  - "Rules of philosophizing," or "Rules of Reasoning in Philosophy" at the beginning of Book 3, pp. 320–21 in Great Minds edition.
- Skim the following, guided by my comments in the prior class. As throughout the course, we need not focus on all the details of the author's science. Read and skim so as to understand the kind of argument Newton is making and the kind of science he presents.
  - Definitions, axioms, sections 1, 2 and 3 of Book 1.
  - Book 3, through Proposition 7.

Week 6 **The 19th-Century Debate over Induction**

Oct 31 Vigorous debates over scientific method arose in the 1830s and ran through mid-century. A particularly prominent and important one was over the nature of induction.

- *Faraday's Experimental Researches in Electricity: The First Series.* The introduction pp. 1–28 is valuable, but if pressed for time, you can skip it at first and refer back to it as needed when reading Faraday's text. The editor's notes at the bottom of the pages can be helpful.
- John McCaskey, "William Whewell (1794–1866)," in *HPS 154 Course Reader*. This is a highly condensed summary of Whewell's epistemology. It will save us a lot of reading.
- William Whewell, "On the Logic of Induction," in *The Mechanical Euclid* (Cambridge, 1837), 172–82. You can find this reprinted in William Whewell, *Theory of Scientific Method*, ed. Robert E. Butts (Hackett Publishing Company, 1989) or online at books.google.com (Google has two editions scanned. The 1838 edition is mis-scanned. Get the 1837.)
- William Whewell, "Establishment and Development of the Idea of Chemical Affinity," in *The History of Scientific Ideas*, vol II. (London: 1858), 15–28. You can find this at books.google.com.
- Richard Whately, "Of Induction," *Elements of Logic*, bk. IV, ch. 1, pp. 255–66 in the London 1848 edition, in *HPS 154 Course Reader*. I have marked the crucial few paragraphs for you.
- John Stuart Mill, *A System of Logic, Ratiocinative and Inductive*. You can buy a hardcopy (there is an outstanding new edition just out from Liberty Fund for only $24) or find a scanned one online at books.google.com or oll.libertyfund.org/Home3/index.php.
    - "On the Ground of Induction," bk. III, ch.III ;
    - "Of the Evidence of the Law of Universal Causation," bk. III, ch. XXI;
    - "Of the Four Methods of Experimental Inquiry," bk. III, ch. VIII.
    - Of these three chapters, you need to read the first two. You might not need to read the third. It explains what are now called "Mill's Methods." You need to know what Mill's Methods are, but you don't really need to read Mill to learn them. They are now explained in shorter and often clearer form in many textbooks and web sites. If you know the methods, you don't need to read Mill's chapter on them.
- William Whewell, *Of Induction with Especial Reference to Mr. J. Stuart Mill's System of Logic* (London 1849), in *HPS 154 Course Reader*.

SECOND PAPER DUE beginning of class November 7.

Week 7 Nov 7 — **Science of the Unobservable: Evolution**

The mid-19th century was also the time of remarkable and provocative scientific advances, many involving things that could not be directly observed, such as electricity, atoms, the distant past, and the core of the earth. In class, we will examine one of these, Darwin's proposal for evolution by natural selection. Read the following, in order.

- Phillip R. Sloan, "The making of a philosophical naturalist," *The Cambridge Companion to Darwin*, pp. 17–39. You can read this lightly, but give attention to section IV, "The Transformation of 1831," in *HPS 154 Course Reader*.
- Charles Darwin, *Origin of Species*, "Introduction" and first four chapters (to page 130 in first edition). You will find you can read through some parts of this quickly, but take care to follow Darwin's overall argument. For class, sketch out his argument in an outline or block diagram—not a lot of detail, just the central three to ten points.
- M. J. S. Hodge, "Darwin's Argument in the Origin," *Philosophy of Science*, Vol. 59, No. 3. (Sep., 1992), pp. 461-464. You can get this at www.jstor.org.
- James G. Lennox, "Darwinian Thought Experiments: A Function for Just-So Stories," *Thought Experiments in Science and Philosophy*, pp. 223–245, in *HPS 154 Course Reader*. You can skip the short Appendix.

Week 8 Nov 14 — **Rise of Statistical Thinking**

- To be determined.

Week 9 Nov 28 — **Quantum Physics: Indeterminism and the Forman Thesis**

- Heisenberg. Selections to be determined.
- Paul Forman, "Weimar Culture, Causality, and Quantum Theory," *Historical Studies in the Physical Sciences*, Vol. 3, pp. 1-115. 1971.

THIRD PAPER DUE beginning of class December 5.

Week 10 Dec 5 — **Mid 20th Century: Karl Popper to Intelligent Design**

- Karl Popper, *The Logic of Scientific Discovery,* pp. 1–73.

OPTIONAL FOURTH PAPER DUE December 14.