The Boldest Hoax

Be Prepared To Discuss the interaction of science and society/culture in the Piltdown Hoax. Consider:

- The varieties of MOTIVATION for scientific activity which are not scientific.
- The connection of the History of Science to “external” factors such as cultural expectations, social trends, politics, personal interests and ambitions, etc.
- The cultural image and role of the “scientist” in Edwardian Britain.

Men Who Made a New Physics

(And What They did for Fun)
The Scientific Community as a Sub-Culture

- Although always members of their respective national, ethnic, or regional culture groups, the scientists involved are also members of a “scientific community.”
- This community possesses has its own distinctive features in:
  - Knowledge and Belief
  - (Including a distinctive worldview)
  - Behavior, Customs, and Social Forms
  - Material Traits
  - Language and Symbolic Representation
- Therefore the scientific community possesses the necessary traits, according to cultural historians, which set it apart as a separate “cultural group.”
- With Men Who Made a New Physics we are turning from an examination of science in society, to include an examination of scientists as a society.

In Reading, Consider:

- The place of the scientists in their respective societies.
- What the distinctive cultural features of this “scientific community” are:
  - What do they believe about the world and their work?
  - What customs and social forms do they follow?
  - What material traits mark the culture of physics? (What does it look like?)
  - What language and symbols dominate the culture of physics?
- How physics, for the physicist, is intensely personal, and a source of passion.
- How the personal traits of the physicists affect their work.
- The difference between how “physics” appears on the “outside” vs. the “inside.”
The Hunting of the Nucleus

- Chapters 1-2 describe the events surrounding a landmark discovery in the dark basement of a laboratory.
- What is the discovery?
- Who are the main characters involved in this story?
- What are they like?
- How do they relate to each other?
- What social customs and forms apply in the laboratories run by Rutherford?

A Little More on Rutherford

- Born, 1871, Nelson, New Zealand.
- The English "father" of modern atomic physics.
- 1894 went to work under J.J. Thomson at the Cavendish Laboratory.
- Developed a radio-wave "receiver" while still a college student in New Zealand.
- Joined the physicists obsessed with "radioactivity" while at the Cavendish (set-up experiments for Thomson relating to it.)
- 1898 left for McGill University in Canada.
- 1898 -- identified alpha and beta rays in uranium radiation.
- 1900 -- married (Mary Newton)
- 1900 -- Working w. Soddy, determined that radiation was an atomic, not molecular, phenomenon, and observed that it involved transmutation of substances (Note his last publication title, The Newer Alchemy)
- 1910/11 -- took the professorship at Manchester, nucleus identified.
- 1913 -- atomic numbers based on properties of different nuclei.
Rutherford, Concluded

- 1914 -- knighted.
- 1920 -- took over the Cavendish Laboratory.
- 1931 -- made “Baron Rutherford of Nelson and Cambridge”
- What he did for fun: golf, “motoring.”
- 4 Nobel Prize winners were directed into their award-winning researches by Rutherford; many more collaborated with him at one time or another.

Max Planck and the German Scene

- What was the German physics community like in the late 19th c.?
  - Customs and social conventions?
  - What about beliefs regarding the physical world?
- What was Max Planck like as a person?
- What characterized Planck’s work style?
- What was Planck’s relationship with his fellow physicists (and who were they)?
  - Von Helmholtz?
  - Clausius?
  - Boltzmann?
- What, basically, is the second law of thermodynamics and what did it mean to Planck?
Max Planck
- Born, 1858, son of a professor of Constitutional Law.
- Studied at Munich and Berlin, doctorate from Munich in 1879.
- Privatdozent in Munich, 1880–85.
- Associate Prof. of Theoretical Physics at Kiel until 1889. (While there took “second place” in the Gottingen Competition.)
- Von Helmholtz arranges for him to join the faculty at Berlin, replacing Kirchoff, in 1889.
- Equation for Black-Body Radiation (treating energy as quanta), 1900.
- Retired from Berlin, 1926.
- President of Kaiser Wilhelm Society until 1937.
- 1944 -- one of his sons is killed after involvement in the plot to assassinate Hitler.
- 1947, died at Gottingen.
- What he did for fun: Piano, Mountain Climbing.

Some Clarifications of Quantum Theory
- Entropy -- the tendency toward disorder. Heat cannot efficiently reorganize itself into Energy.
- Boltzmann contended that this could be best understood if heat were recognized as molecular motion.
- While this led him to entropy as certainly as Planck’s demonstrations of Clausius, it made entropy a statistical probability, not an absolute law, as Planck insisted. Planck would have to back down on this.
- “Ultraviolet Catastrophe” -- the “impossible conclusion” that energy must increase to infinity with the infinite reductions in wavelength at the ultraviolet end of the spectrum.
- Planck solved this with an equation which treated light not as a “wave” but as “particles”
- “Light” could thus be given an “amount,” quantified, it is not itself infinite, but seen as definite quantities, or “quanta.”
- Energy did not have to be infinite either, and it did not approach infinity with the decrease of wavelength (Energy existed as a finite quantity ranged along the spectrum).
- All of this assumes discontinuity rather than continuity -- energy changes in very small jumps, not varying continuously.
I Irony:
- Planck spent many years trying to prove his quantum equation wrong, and arrive at the explanation of black-body radiation without sacrificing continuity (and the absolute nature of entropy).
- He could not do it.
- Planck received the Nobel Prize in Physics in 1918, for his discovery of the quantum nature of light radiation.
- In other words when his work was finally recognized, it was for establishing something that he desperately wanted to disprove.
- Planck’s own mistrust of his work contributed to its slow adoption by the physics community (along with distracting phenomena such as X-rays).
- Einstein was the key figure in applying quantum theory beyond the case of Black-Body radiation.

Enter Einstein
- What was Einstein like?
- How did he do in school?
- What role did the Patent Office play in his life?
- What about his religious convictions?
- What role did his perspective on German academic society play in his life?
- What did he do for fun?
1905:

- Photoelectric Effect: discovered that this effect operated according to Planck's presentation of light energy as "quanta." Thus there is a relation between energy in light and the corresponding levels of energy in matter.
- Special Theory of Relativity: dealing with the problem of light and travel in a straight line -- resolves the paradox of "light standing still" by recognizing that neither time nor space are absolute references, but vary with motion. (Thanks, Ernst Mach.)
  - (Light may be understood as constant relative to time perceived from any number of moving vantage points.)
  - (This permitted a mathematical explanation of the light speed experiment of A.A. Michelson which had demonstrated that the speed of light was an absolute constant.)
- Byproduct: the equation $E = mc^2$, (providing the numeric basis for the energy released by mass converted to energy w. the splitting of the atom.)

Born, 1879, son of a businessman in Ulm.
- Kicked out of school when he was 16 for being a disturbance.
- Failed the entrance exam to Zurich Polytechnical Institute, and went back to "high school."
- 1896, entered the Institute.
- 1901, graduated, went to work at the Swiss Patent office.
- 1903, married Marina Maric, a Serbian mathematics scholar.
- 1905 received his doctorate, published 3 articles on: Brownian Motion, Photoelectric Effect, Special Theory of Relativity
- 1908, Privatdozent in Berne.
- 1909, Professor "extraordinary" at Zurich.
- 1911, Professor of theoretical physics at Prague.
- 1912, Professor of the same at Zurich.
- 1913, invited by Planck to come to Berlin.
- 1919, marriage w. Maric dissolved, marries his cousin, Elsa Lowenthal.
- 1921, Nobel Prize, physics, for the law of the photoelectric effect.
Einstein Concluded:

- 1933, renounces German citizenship, moves to America, Professor of Theoretical physics at Princeton.
- 1940, becomes an American Citizen.
- 1945, retires.
- later '40s, offered presidency of the new state of Israel (declined), and co-founded the Hebrew University of Jerusalem.
- Died, April 18, 1955, Princeton.

Niels Bohr

- born, 1885, son of a professor of physiology in Copenhagen.
- 1909, masters degree, 1911, Ph.D. U. of Copenhagen.
- 1912, At Manchester under Rutherford. (Married in the same year to Margarethe Nørlund. Six sons, two of whom died before adulthood.)
- 1913, Lectureship in Physics at Copenhagen. Begins to apply quantum theory to electrons in the Hydrogen atom.
- 1914-16 taught at Manchester.
- 1916, Back to Copenhagen. Kramers becomes the first associate in the “Institute for Theoretical Physics.”
- 1922 -- Nobel Prize in Physics for the structure of the atom.
- 1930 -- turns to the study of the nucleus.
- W.W. II -- Bohr escapes Nazi occupation of Denmark. Flees to Sweden, spends last two years of the war in U.S. and U.K. advising the Atomic Energy Project.
- Later years devoted to peaceful applications of nuclear power, and prevention of nuclear war.
- Died, Nov. 18, 1962.
Bohr's Quantum Theory of the Atom

Based on observations of the specific spectra Bohr discovered that the same type of jumps in energy levels which Planck recognized in Black Body radiation, and which Einstein had identified in the photoelectric effect applied to electron energy levels.

If the energy of electrons is discontinuous, according to Bohr's model, it accounts for the electron not spiraling into the nucleus, and not ordinarily emitting radiation.

(See pp. 100-101)

This leads to the general “shell model” explaining chemical phenomena on the atomic level. (cf. p. 114)

What are some of the problems with this model? (116, 119, 121)

What is “correspondence” in Bohr's method? (116)

The “Institute” as a sub-culture:

- What was life at the Institute like?
- How was work accomplished there?
- What were some of the material characteristics defining the Institute?
- What was Bohr like as a person? How did he work?
- Wolfgang Pauli?
- (What was the “Pauli Effect?”)
- Werner Heisenberg?
- Paul Dirac?
- Who was Schrödinger and what did he have to do with the Institute?
- Max Born?
- What did they do for fun?
- Why did Bohr travel so much?
What others did:
- Pauli: “Exclusion Principle” -- no two electrons may move in the same way. (Accounts for the differences between Bohr’s “shells”). Pauli also proofread and ironed-out everyone’s math.
- Heisenberg developed a unified approach to both atomic phenomena and the classical “large scale” phenomena of physics -- key turns out to be a form of matrix algebra.
- Max Born: recognized the nature of Heisenberg’s work, and, along with Jordan, developed it into a complete theory.
- (Dirac: came to Born and Jordan’s conclusions from another angle.)
- (Pauli: used the new method to calculate the hydrogen spectrum.)
- De Broglie: identified the dual nature of the electron.
- Schrödinger: developed de Broglie’s observation into “wave mechanics” in an attempt to save the “deterministic” mechanical predictability of physics.
- Bohr: invited Schrödinger to Copenhagen. Poked particle-shaped exceptions into his wave rules for electron motion.
- Heisenberg: ”indeterminacy” or “uncertainty” principle -- explained why, because of the influence of the observer upon the experiment, momentum or location of a particle must always remain unknown. (Similarly, “frequency” is an externally imposed assumption.)

Quantum Mechanics: What Can and Cannot be Known
- Electrons are neither particles nor waves, but to understand them we must recognize both wave and particle properties in their behavior. (168-69)
  Electrons are not ‘things.’
- As Schrödinger demonstrated it, wave mechanics is the most convenient way to understand electron behavior under “normal” (terrestrial) conditions, and it eliminates Bohr’s “conscious electrons.”
- “The Ghost in the Machine” -- the experiment and the experimenter always influence the outcome of the experiment. At the atomic level the instruments (whether light or matter) have a significant effect. (This leads to . . .)
- Heisenberg’s “uncertainty” principle: Conceived as a particle, an electron’s position or momentum will be unknown. Therefore:
  “Probability” rather than “certainty” is the rule at the atomic level (and all other levels, although the appearance of certainty is very strong at larger levels because the probability is greater.)
- Therefore, Quantum Mechanics is fueled by statistics.
- Waves also vary according to quanta (198)
- Classical determinism is indefensible.
Werner Heisenberg

1901-1976. Son of Middle/Modern Greek language professor at the University of Munich.

Attended the Maximilian Gymnasium in Munich until 1920. (Same school as Einstein.)

1919 -- participated in the overthrow of the “Bavarian Soviet Republic,” the Communist government which had been established in Munich after W.W. I.

1923 -- Ph.D. from Munich, went to work under Born at Gottingen.

1924 -- met Bohr, received a grant to work at the Institute in Copenhagen.

Back to Gottingen in the summer of ’25, went to Heligoland for hayfever and mountain climbing, and developed quantum mechanics. Back to Copenhagen in 1926 as a lecturer.

1928 -- professor at Leipzig.

1929 -- lecture tour of U.S., Japan, India.

1932 -- Nobel Prize for Physics.

1936-37 -- under suspicion by the S.S.

1937 -- Marries Elizabeth Schumacher -- 7 kids.

1939 -- leading physicist on the German Uranium Fission Research project.

1941 -- travelled to German occupied Copenhagen to lecture, and meet with Bohr (The mystery of this meeting is at the heart of the play, “Copenhagen.”) After the meeting the friendship between the two, once very close, was effectively over.

1942 -- director of the Kaiser Wilhelm Institute after Planck.

1942 - '44: continues directing nuclear fission research for the Reich.

July 1945: Arrested and detained by the Allies in England along with 9 other physicists. Interrogated.

1946 -- lecturer in Gottingen, placed in charge of the Kaiser Wilhelm Institute, again, now named the “Max Planck Institute.”

1954 -- delegate to ”Atoms for Peace” Conference.

1957 -- joined in a declaration against West German nuclear weapons.

1958 -- Moved Planck Institute to Munich.

1976 -- died in Munich.

What he did for fun (other than physics): hiking, skiing, sailing, climbing, piano.
“Copenhagen Interpretation”
○ Heisenberg’s “uncertainty principle” and Bohr’s “complementarity principle” (wave and particle theories must be used together) are both applied as “givens” in the interpretation of quantum mechanics.
○ First presented at the Solvay Conference of 1927.
○ Einstein, expected to be a major supporter, opposed Bohr there, and kept up his opposition to Quantum Mechanics for the rest of his life (in some form).
○ The heart of the debate lies not in the physics proper, but in a fundamental difference in belief which existed between Einstein and Bohr.
○ The “General Theory of Relativity” sheds light on this difference.

Relativity II: The “General Theory”
○ The Special Theory of Relativity had dealt with a specific case -- linear motion.
○ Einstein was obsessed with removing all contradiction and all unnecessary complexity from physics.
○ “God is sophisticated but he is not malicious” the universe could be understood because, if understood correctly, Einstein believed, it was completely consistent.
○ In this spirit he attacked an inconsistency in Newtonian physics between the law of gravity and the law of inertia.
○ After 10 years Einstein hit upon the key: if space and time were combined into a single fabric, or “continuum,” then the inconsistency would be resolved if it were recognized that “gravity” was not a “force” (as if it reached outward from objects) but a bending, or a curved area, in the space-time continuum. (See conclusions on 228 ff.)
○ Note the cultural side-effects on pp. 229 ff.
○ The General Theory increased the “certainty” and predictive power of physics.
○ It was in line with Einstein's core belief that he was studying a “pattern.” Neils Bohr did not share Einstein’s belief about what he was studying.
Bohr v. Einstein

At the Savay Conference Bohr expected support from Einstein. He was unaware of the strength of Einstein's belief in consistency.

Einstein was horrified by the suggestion of fundamental unknowability in the Copenhagen Interpretation. (p. 240–41)

Bohr, for his part, did not believe that the study of physics was about the complete understanding of objective laws, but about describing physical phenomena with the human, and imperfect, invention of mathematical language. (241–42)

Einstein proposed numerous thought experiments to disprove the uncertainty principle.

Bohr found flaws in all of them, though the "Box of Light" experiment, proposed by Einstein in 1930, had Bohr stymied, until he realized that Einstein's own General Theory of Relativity served to guarantee "uncertainty." (238–40)

Physics had threatened to become a genuine crisis of faith for one or the other.

Einstein was the one who wound up with the crisis in the end.

"Determinism" was the main casualty of the triumph of Quantum Mechanics.