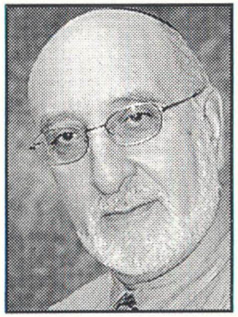

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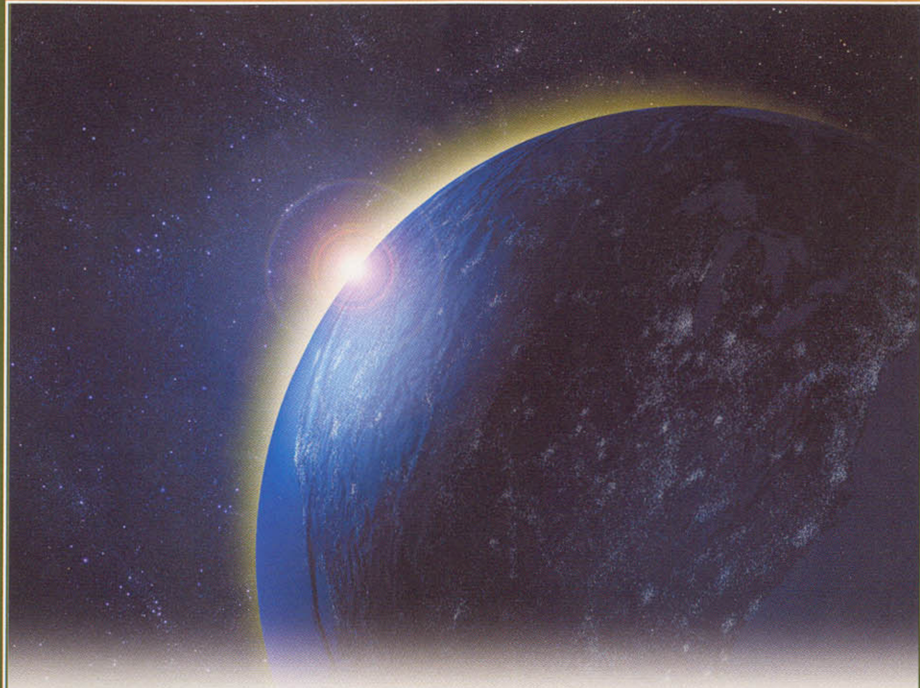

Science in the Twentieth Century:
A Social-Intellectual Survey

Taught by: Professor Steven L. Goldman,
Lehigh University

Part 3

Course Guidebook

THE TEACHING COMPANY®

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Steven Goldman has degrees in physics (B.Sc., Polytechnic University of New York) and philosophy (M.A., Ph.D., Boston University) and, since 1977, has been the Andrew W. Mellon Distinguished Professor in the Humanities at Lehigh University. He has a joint appointment in the departments of philosophy and history because his teaching and research focus on the history, philosophy, and social relations of modern science and technology. Professor Goldman came to Lehigh from the philosophy department at the State College campus of Pennsylvania State University, where he was a co-founder of one of the first U.S. academic programs in science, technology, and society (STS) studies. For 11 years (1977–1988), he served as director of Lehigh's STS program and was a co-founder of the National Association of Science, Technology and Society Studies. Professor Goldman has received the Lindback Distinguished Teaching Award from Lehigh University and a Book-of-the-Year Award for a book he co-authored (another book was a finalist and translated into 10 languages). He has been a national lecturer for Sigma Xi—the scientific research society—and a national program consultant for the National Endowment for the Humanities. He has served as a board member or as editor/advisory editor for a number of professional organizations and journals and was a co-founder of Lehigh University Press and, for many years, co-editor of its Research in Technology Studies series.

Since the early 1960s, Professor Goldman has studied the historical development of the conceptual framework of modern science in relation to its Western cultural context, tracing its emergence from medieval and Renaissance approaches to the study of nature through its transformation in the 20th century. He has published numerous scholarly articles on his social-historical approach to medieval and Renaissance nature philosophy and to modern science from the 17th to the 20th centuries and has lectured on these subjects at conferences and universities across the United States, in Europe, and in Asia. In the late 1970s, the professor began a similar social-historical study of technology and technological innovation since the Industrial Revolution. In the 1980s, he published a series of articles on innovation as a socially driven process and on the role played in that process by the knowledge created by scientists and engineers. These articles led to participation in science and technology policy initiatives of the federal government, which in turn, led to extensive research and numerous article and book publications through the 1990s on emerging synergies that were transforming relationships among knowledge, innovation, and global commerce.

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Science in the Twentieth Century: A Social-Intellectual Survey Part III

Science in the Twentieth Century: A Social-Intellectual Survey

Scope:

In the course of the 20th century, the practice of science, professionally, intellectually, and in relation to society, increased in scope, scale, and complexity far beyond what had been anticipated at the end of the 19th century. All of the sciences became inextricably entangled with social, political, and commercial forces and values. From the perspective of society, at least, this erased the distinction between pure and applied science, between knowledge and its "fruits," which had been passionately espoused by many leading 19th-century scientists. As scientists created increasingly powerful theories, people—often scientists themselves—applied those theories to develop technologies whose exploitation created new wealth, new forms of power and control, new ways of life...and new dependencies on more science to create newer technologies!

Concurrently, the practice of science became increasingly formalized, institutionalized, and professionalized. This professionalization reflected and was driven both by the rise of a large number of people who made a living as scientists, in comparison with the comparatively modest community of mostly gentlemen scientists in the 19th century, and by the steadily increasing significance of science to society from the last third of the 19th century through the 20th century. Two hundred and fifty years after the pioneering work of Descartes, Francis Bacon, and Galileo, science suddenly mattered—not just to intellectuals, but to everyone and in profoundly existential ways.

Intellectually, too, the discoveries and theories of 20th-century physical, life, and social scientists exceeded anything that had been anticipated, even by the greatest of 19th-century scientists. As 1900 approached, leading physicists claimed that, apart from the details, the task of science was nearing completion; however, by the end of the 20th century, effectively every 19th-century theory of natural and social phenomena would be overthrown or superseded.

The first lecture in this course establishes its objective: to trace an intellectual history of the physical, life, and social sciences in the 20th century, organized around an evolving scientific understanding of matter and energy, the universe, Earth, life, and humanity, subsuming under the last category theories of culture, society, and mind.

Complementing this survey of a century of science from the "inside," in terms of its ideas and discoveries, will be an account of the evolution of 20th-century science from the "outside," that is, of its evolving relationship with society. It is this reciprocal relationship between science and society that makes an understanding of the sciences as a whole in the 20th century important, and not simply as history, because science is implicated in all of our 21st-century prospects, the threats no less than the promises.

Lectures Two though Eleven describe our evolving understanding of matter and energy, the foundations of the physical and life sciences. We begin with the special and general theories of relativity and how they redefined what we mean by space, time, matter, energy, and motion: in short, what the framework of reality is for the physical sciences.

Given that quantum theory is the most important and intellectually revolutionary scientific theory of the 20th century, eight lectures are devoted to it. Lectures Three and Four trace the early history of the theory, from the tentative introduction of the quantum hypothesis in 1900 to the formulation of quantum mechanics in 1925 and its radical Copenhagen interpretation in 1929. Our goal is a qualitative appreciation of the innovative ideas underlying the theory and of the bizarre microworld underlying ordinary experience that it revealed. Lectures Five through Eight describe the creation and application of the second stage of quantum theory's development, quantum electrodynamics (QED), from 1929 to 1965. Lectures Nine and Ten describe the transition from QED to quantum chromodynamics (QCD) and the unification of all known fundamental forces of nature.

Lecture Eleven concludes the discussion of matter and energy by highlighting major events in the evolution of chemistry, emphasizing the transformation wrought by its assimilation of quantum theory and its growing power to create molecules by design.

The obscurity of the theories of 20th-century physical science from the perspective of the non-scientist public is overwhelmingly a consequence of the forbidding mathematics that has become the language of science. Lectures Twelve and Thirteen discuss controversies in the first half of the 20th century over the relationship between mathematics and truth, and between mathematics and reality, as well as the astonishing fertility of abstract mathematics for the sciences, even if the source of that fertility is not understood.

What we mean by the *universe* has changed, from 1900 to 2000, far more dramatically than anything else in the history of science, more even than the change wrought by Copernicus. Today, the universe is unimaginably more vast than it was thought to be in 1900, and the stories of its origin, constitution, and fate, discussed in Lectures Fourteen through Sixteen, are beyond science fiction!

Lectures Seventeen through Nineteen focus on our knowledge of planet Earth, especially the shift from a geology of static continents to plate tectonic theory. We also discuss the growing recognition of the Earth as a complex system, integrating a dynamic, evolving, physical Earth with its biosphere, oceans, atmosphere, and external and internal magnetic fields, the whole interacting with the solar system in general and the Sun in particular.

Lectures Twenty and Twenty-One address the "outside" of science, especially the rise of techno-science (science-based technology) and its connections to government, industry, and society.

Lectures Twenty-Two through Twenty-Six address our understanding of life, treating the history of evolutionary biology, human evolution, genetics, molecular biology, and science-based medicine.

Lectures Twenty-Seven through Thirty-Four focus on our knowledge of humanity. This group includes three lectures on the evolution of anthropological theories of human culture, the field and theoretical work of archaeologists, important developments in linguistic theory, and changing conceptions of history as a science. Three lectures describe theories of society, the state, and economies, theories that have had profound implications for national and global political agendas and actions in the course of the 20th century. Two lectures describe changing theories of the human mind, our most intimate attempt at self-understanding, from the enormously influential theories of the unconscious by Freud and Jung early in the century, through the equally influential behavioral psychology that dominated the mid-century, to the cognitive psychology that came to the fore in the late century, especially cognitive neuroscience allied to artificial intelligence research.

Lectures Thirty-Five and Thirty-Six review the major concepts of 20th-century science and discuss their broader cultural and intellectual significance, survey the leading edges of the sciences at the close of the 20th century, and look ahead to the continuing evolution of science in the 21st century.

Lecture Twenty-Five
Molecular Biology

Scope: There is more to life than genetics! The atomic theory of matter had become a dogma of science only in the second decade of the 20th century, but already, the course of biological research had shifted from the study of organs and organisms to the study of the chemical and, ultimately, molecular bases of metabolic processes. This brought into biology, first, chemists and, from the late 1930s, people trained as physicists. With the new people came new approaches to identifying and solving biological problems. The assimilation of biophysics and biochemistry was reflected in the centrality to research programs of identifying fundamental "elements" of cellular processes and discovering their chemical compositions and atomic structures. Initially, the focus was on enzymes, but by the end of the century, the success of these programs, evidenced by the DNA story, brought information theory into biology in the form of bioinformatics and highlighted *proteomics*, discovering the complex folded structures of proteins, as the key to understanding life.

Outline

I. By the end of the 20th century, molecular biology was the dominant focus of life science research.

A. The term *molecular biology* was used in 1938 by Rockefeller Foundation President Warren Weaver. Molecular biology is an expression of the steady growth of biochemistry and physical chemistry in explaining metabolic processes.

1. The term *biology* was coined in the early 19th century to identify a discipline for studying the special phenomena associated with life. A generic term for the force that was distinctly associated with life was *vitalism*, or *élan vitale*.
2. In this sense, biology in the early 1800s was out of step with the rest of physical science, which was materialistic, deterministic, and mechanistic.
3. Hence, there was a strong push to interpret the vital force physically, chemically, and mechanistically. For this reason, in the course of the 19th century, chemistry and biology became intertwined.
4. Biology, however, was still interested in the processes of life, which typically brought the focus to the level of organisms and organs.

5. The molecular approach focuses quite narrowly on molecular processes and on structure as a determinant of physiological processes.
6. As we shall see, it was in biology that *reductionism* first manifested itself, that is, the reduction of life phenomena to nonliving physical and chemical phenomena and, ultimately, to structural relationships among forces and particles.

B. The debate between reductionism and vitalism continued from the 1850s to the end of the 19th century, but by 1938, reductionism seemed to have won. How did biologists move from studying organisms, organs, and physiological processes to molecular processes?

1. Ivan Pavlov, in 1902, began his studies of conditioned reflexes that, in the 1920s, became a long-term research program in the physiology of behavior. In principle, all human behavior was seen as a manifestation of complex conditioned reflexes. This view was one step toward a mechanistic interpretation of life, and it was influenced by many other steps in that direction in the first few decades of the 20th century.
2. Jacques Loeb, first, in Germany, then, in the United States, championed a mechanist view of life, supported by his research on tropisms and artificial fertilization. His 1912 book *The Mechanistic Conception of Life* was very influential.
3. Concurrently, scientists were finding mechanistic reductions of animal behavior that were translated into human behavior. In 1911, Edward Thorndike published *Animal Intelligence*, which together with Pavlov's work on conditioned reflexes, led John Watson to publish his text on behaviorism in 1913. This view holds that human beings don't act; they react to external stimuli.

C. Increasingly sophisticated physiological studies also enabled plausible arguments for the "machine-like" character of human beings.

1. Charles S. Sherrington in England, for example, exposed the detailed neurophysiology of the reflex arc and identified inhibition as a critical factor in muscular action.
2. In the United States, L. J. Henderson and Walter B. Cannon, colleagues at Harvard Medical School, added complementary studies that advanced a physical interpretation of life: Henderson, of internal self-control mechanisms in mammals, which he modeled mathematically, for example, in his 1921–1931 lectures on blood; Cannon, on the action of the sympathetic nervous system, coining the term *homeostasis* to describe the means by which bodily processes act to sustain "dynamic equilibrium."

D. Between 1900 and the 1930s, then, there was a growing body of scientific work supporting the view that, ultimately, all human behavior—both physiological and psychological—can be explained by physical and chemical processes.

E. At the same time, in chemistry, there was a growing emphasis on structure as the key to chemical properties.
   1. By the end of the 1920s, most biologists agreed that biological molecules are long molecules with precise structures and shapes.
   2. One of the great 19th-century discoveries was the importance of spatial arrangement to the chemical and physical properties of molecules.
   3. The combination of reductionism in biology with the focus on structure in chemistry gave birth to molecular biology.
   4. The next logical step was to reduce biology to the study of the structure of molecules in order to understand life processes.

F. Let's look at one concrete example of the reduction of life processes to structure.
   1. In 1949, Linus Pauling, who had, since 1940, called for a molecular description of the antigen-antibody reaction and would, in 1951, identify the alpha-helix structure of proteins, gave a molecular account of sickle cell anemia.
   2. The victim's hemoglobin had an anomalous electric charge, caused by a single amino acid error in one protein, that warped the cell's shape so that it could not flow through narrow blood vessels.

II. Molecular biology has been described as having three "strands."

A. The chemical and the structural are two of these strands, and the third is information, which emerged in the 1950s and reflected a second wave of physicists taking an interest in biology. This manifested itself strongly in the case of Watson and Crick and the interpretation of DNA.

B. The 1948 book *Cybernetics* by Norbert Wiener described apparently purposeful behavior displayed by machines, attributed to self-control mechanisms based on feedback loops. In the same year, Claude Shannon and Warren Weaver published the foundational paper in modern information theory.

C. By the end of the 1940s and early 1950s, physics was focused on information as a principle of reality, analogous to structure.

D. Watson and Crick's discovery of the structure of DNA prompted the question: What does DNA do?
   1. George Gamow noticed a peculiar correlation between the number of combinations of the 4 DNA bases and the number of amino acids used to make proteins. Could there be a functional connection between the base sequences and the amino acids?
   2. Crick and others in the 1960s–1970s worked out the DNA base sequence "code," confirming Gamow's idea that DNA is an information structure, a code book for manufacturing proteins.

E. Recall that in the early 1900s, the gene was conceived as analogous to the atom in chemistry and physics. The work of Jacques Monod and François Jacob revealed that genes act through networks, not individually.
   1. The network of genes triggers the manufacture of certain proteins at certain times and for particular cells.
   2. In fact, at the end of the 20th century, scientists were questioning the existence of individual entities called *genes*.

F. To say that DNA is an information structure seems unsatisfying on some level. DNA is the code for making proteins, and proteins trigger certain cellular processes, but does this fact answer the question: What is life?

G. At the end of the 20th century, we see a severe disconnect between genetics at the level of molecular biology and the classic concern of biology. What sense can we make of the revelation that life is an information structure?

Essential Reading:

Michel Morange, *A History of Molecular Biology*.

———, *The Misunderstood Gene*.

Supplementary Reading:

James D. Watson, *DNA: The Secret of Life*.

Questions to Consider:

1. How strong is the case for reductionism? Is it more or less threatening than the idea of evolution to traditional conceptions of the meaning of life?
2. What are the implications for our understanding of life and reality of interpreting the DNA molecule as a carrier of information?
3. Why do we persist in positing "atomic" mechanisms for new natural phenomena even after the shift to process and relational models in explaining other phenomena?

Lecture Twenty-Six
Molecular Medicine

Scope: Like mathematics, though for different reasons, medicine is not, strictly speaking, a science, and the history just of 20th-century medicine demands a course of its own. Nevertheless, the essence of 20th-century medicine, as of 20th-century technology generally, surely is its science-based character. Furthermore, the theories, concepts, and diagnostic and therapeutic tools that were a driving force in the evolution of 20th-century medicine echoed parallel developments in biology. The development of serums and vaccines, theories of disease and models of the ways they spread; the use of X-rays, fluoroscopy, CAT scans, and magnetic resonance imaging; the embrace of genomics and the pursuit of genetic engineering—all are illustrative of the assimilation into medicine of physics- and chemistry-derived influences.

Outline

I. Medicine in the 20th century reflects the same influences from physics and chemistry that were at work in research biology.

A. Twentieth-century medicine is associated with dramatic changes in the lifestyle of the public in developed countries. For example, the life expectancy in the United States in 1900 was 47 years and a few months; today, it is in the high 70s.

B. The speed with which Watson and Crick's abstract and fundamental work in molecular biology has entered the mainstream of medical practice is phenomenal.

1. Just four years after the discovery of the structure of DNA, Arthur Kornberg identified the enzyme responsible for bonding the base pairs of DNA.
2. In 1972, Paul Berg performed the first successful recombinant DNA experiment, and over the next five years, techniques were developed for disassembling DNA at will. Berg became concerned about the ethics of recombinant DNA technology and prompted the establishment of safety procedures for labs involved in DNA research.
3. In 1977, bacteria were used to synthesize human somatostatin. In 1980, the human interferon-producing gene was inserted into a bacterium for mass production, and in 1982, the FDA approved genetically engineered human insulin produced by bacteria.
4. In 1980, the first transgenic plants and animals were created, and the possibilities for commercialization of this technology were recognized.

5. In 1983, the first monoclonal antibody was approved for a diagnostic test, suggesting that medicine might be able to produce unlimited quantities of highly specific antibodies to fight disease. In 1985, recombinant DNA technology was used to produce Human Growth Hormone commercially, and in 1986, the first antibody-enzyme hybrids were created, launching a new class of pharmaceuticals.
6. In 1997, the first artificial human chromosome was created, suggesting the potential of molecular biology to provide increasingly powerful therapeutic tools.

C. Twentieth-century medicine also saw the development of molecular psychiatry, that is, the reduction of mental processes to the structure of molecular processes. Examples include study of the relationship between the serotonin-producing gene and suicidal behavior and between the serotonin transport gene and depression as a response to stress; between proteins and anorexia; and between the neuregulin-1 gene and schizophrenia.

II. The history of the pharmaceutical industry and of medical imaging technologies reveals other dimensions of the extent to which the evolution of 20th-century medicine has been driven by its assimilation of molecular biology.

A. An illuminating historical case study looked at the evolution of one turn-of-the-20th-century company, Philadelphia-based H.K. Mulford, which produced and marketed bacterial vaccines and vaccine-use kits, along with serum anti-toxins, which added up to a "high-tech" product line for the day.

1. Mulford sought help from an entrepreneurial fellow graduate of the Philadelphia College of Pharmacy, hired academic researchers as consultants, and adopted a marketing strategy based on product innovation, research on dosage standardization, a reputation for quality, and accompanying documentation.
2. The company thrived until the mid-1920s when innovation flagged, and in 1929, Baltimore ethical drug distributors Sharp and Dohm bought Mulford to gain access to the biologicals market.
3. Sharp and Dohm invested heavily in research and production innovation in the mid- to late 1930s, manufacturing sulfa drugs, followed by penicillin and streptomycin. In the process, they dropped effective polyvalent bacterial vaccines because of the public fascination with antibiotics, then developed blood products, for which World War II provided a massive market. (Their process of dehydration and rapid freezing to preserve plasma became a major consumer food technology after the war.)
4. In the 1950s, Sharp and Dohm research and product development shifted from antibiotics to viruses under both public and

government pressure to treat polio. In 1953, Merck, a supplier of fine chemicals and a manufacturer of synthetic vitamins, steroids, and antibiotics, merged with Sharp and Dohm in order to integrate vertically.

5. Merck moved aggressively into viral vaccine research and mass production of the poliovirus vaccine, in the 1970s shifting its research focus to molecular biology and DNA-based molecular genetics products. Bacterial vaccines were revived in the 1980s, this time using recombinant DNA technology, in which a virus is used as a gene delivery *vector*, or transmission mechanism.

B. This case study represents just one example of how the pharmaceutical industry has moved in the direction of molecular therapeutic products.

III. Medical imaging technologies reveal a different route to molecular medicine.

A. X-rays were the first medical-imaging devices.

1. Roentgen discovered X-rays in 1896, and by 1899, Edison was marketing fluoroscopes; by 1910, machines for medical and for dental practices were in production. But these were very crude machines, with exposure times measured in many minutes, and the causes of many injuries, especially to their operators.
2. William David Coolidge of MIT and General Electric's industrial research laboratory developed a much-improved X-ray tube that reduced exposures to seconds. World War I created a market for portable X-ray equipment and a demand for thousands of people trained to operate that equipment. Not incidentally perhaps, in the 1920s, chest X-rays became routine, in part sparked by tuberculosis fears.

B. CAT scanners are a sophisticated enhancement of the X-ray phenomenon, although both technologies provide "outside-in" imaging.

1. In 1929, the idea was first broached for rotating an X-ray tube around a patient and creating a series of image slices that, in the late 1930s, was called *body-section roentgenography*. It was not until 1972 that the first commercial scanner was marketed by EMI of England, after which the technology developed very rapidly.
2. The underlying technology of CAT scans is based on a mathematical tool that has no relationship to medical imaging—*tomography*, a method for building two-dimensional images from one-dimensional data and three-dimensional images from two-dimensional data.

C. The ultimate molecular medical-imaging devices are magnetic resonance imaging (MRI) and positron emission tomography (PET) scanners. These "inside-out" technologies allow us to image, not just bones and tissue, but processes in the body.

1. In 1939, Columbia University physicist I. I. Rabi measured the *magnetic moment* of the atomic nucleus, that is, the way in which the nucleus is magnetized. In 1952, the technique was adapted to measure atomic features of bulk matter, and it became an instant success in physics and chemistry research, with many industrial testing applications.
2. The first NMR/MRI images (keyed to the nucleus of the hydrogen atom) of the human body came in 1981, and when superconducting magnets were adopted in 1986, the results were spectacular. Fast, so-called functional MRI machines in the 1990s allowed real-time imaging of brain processes, for example.
3. In positron emission tomography, radioactive substances are injected into the body to build up an image of the organs in which the molecules of the tracers are contained.

D. These technologies represent the spread of the mindset of the same ideas that were foundational to molecular biology.

Essential Reading:

Louis Galambos and J. E. Sewell, *Networks of Innovation: Vaccine Development at Merck, Sharp and Dohme, and Mulford, 1895–1995.*

Bettyann Kevles, *Naked to the Bone: Medical Imaging in the Twentieth Century.*

Paul Rabinow, *Making PCR: A Story of Biotechnology.*

Questions to Consider:

1. How can patients be re-integrated given the powerful dis-integrating tendencies underlying scientific and, especially, molecular medicine?
2. Is there a disconnect between medical definitions of health and commonsense conceptions of well-being?
3. Is there a threat to our humanness in molecular medicine even as its power to heal grows?

Lecture Twenty-Seven
Culture—Anthropology and Archaeology

Scope: The study of how non-European, especially non-literate, peoples lived was initiated as a science in the 19th century. Anthropologists spread out around the world, as naturalists had been doing for centuries, collecting interesting human "specimens," identifying their distinctive behaviors, photographing them, classifying them. By the early 20th century, anthropology was an established science, but there was still unease over what its object was and what its methodology ought to be. If the object is "culture," what exactly is that? Is the goal simply collecting lifestyle data and reporting them or discovering underlying patterns and themes common to all cultures? Is European culture "privileged," a basis for making cross-cultural value judgments, or must the values of all cultures be accepted as valid in context? Is there a universal human nature that is expressed in many different ways, or is that a European myth, in which case, cultural diversity is an irreducible fact? Concurrently, archaeology went through a parallel development. It, too, began in the 19th century but flowered in the 20th, evolving from collecting and dating to reconstructing lifestyles and bringing physics, chemistry, geology, and biology to bear on this interpretive process. The result of 100 years of scientific anthropology and archaeology has been a more sophisticated and much more complex picture of human being than existed in 1900.

Outline

I. We now turn, in our intellectual odyssey, to the major ideas in the social sciences, ranging from anthropology, through linguistics, to psychology and the cognitive sciences.

- **A.** Along with the physical sciences, the social sciences are also part of the cultural phenomenon of science in the 20th century and have had profound implications for society, analogous to the impact of the physical sciences.
- **B.** Surprisingly, there are also analogies between the conceptual structures of the social sciences and the physical sciences. Certain basal ideas, including the reality of relationships and the power of structures, cut across disciplines.

II. The human sciences, or the social sciences, may seem "unscientific" in comparison to the hard sciences, because they seem to violate the fact-value dichotomy that is a fundamental principle of modern science.

- **A.** The subject matter of the human sciences explicitly incorporates value judgments, by contrast with the physical and life sciences, whose subject matters are value free.
  1. This poses a serious methodological problem for modern science, which insists on an absolute distinction between facts and values.
  2. This also raises the question of whether it is even possible for value-laden matters to be studied scientifically. In late-19th-century Germany, a distinction was drawn between *Naturwissenschaft* ("natural systemic knowledge," namely, hard science) and *Geisteswissenschaft* ("human science") in order to sustain a scientific status for the study of humanity.
- **B.** Conceptually, anthropology precedes the other human/social sciences, though effectively, all of the others are older chronologically.
  1. The core concerns of anthropology all revolve around the question: What does it mean to be human? We might also ask: How can we study this question scientifically?
  2. The empirical methodology of anthropology, that is, the collection of information about how people live, does not seem to constitute a science, because it does not have explanatory power.
  3. Developmental sequencing is a way of converting a collection methodology into an explanatory methodology.
  4. Early in the history of anthropology, culture became the primary focus of study.
- **C.** The next logical questions were: What is the methodology for studying culture and what is *culture*?
  1. Is there such a thing as *culture*, or like the terms *species* or *style* (in art), is *culture* a convenient name for an aggregate of practices? Can a culture exert forces/influences on its members? Do cultures develop over time in lawful ways, by deliberate choice, or haphazardly?
  2. Two giants of early-20th-century British anthropology, Bronislaw Malinowski and A. R. Radcliffe-Brown, took a functional approach to these questions from opposing perspectives: Malinowski, taking a people's practices and institutions as ways of responding to individuals' biological, psychological, and sociological needs; Radcliffe-Brown, beginning with social practices and how they shaped individuals in their image.
  3. Meanwhile, German anthropology was primarily ethnological, studying practices and the detailed forms they took, and American anthropology was primarily cultural.

III. In anthropology, as in the social sciences generally, American influence rapidly became dominant.

- **A.** A German immigrant to America, Franz Boas, was a major influence on all of the social sciences in the first half of the century. Boas was a relativist, rejecting the claim that all cultures evolved according to a single law and insisting on the integrity of all cultures and the need to understand each in context.

1. Boas's students, among them, Ruth Benedict (*Patterns of Culture*) and Margaret Mead (*Coming of Age in Samoa*), created a powerful culturally relativist anthropological school centered on the relationship of culture and personality.
2. This school was interested in understanding how personality reflected the internalization by individuals of their cultures, including modern cultures (which brought anthropology and sociology together). Some members rejected anything resembling a Freudian unconscious; others (Abram Kardiner, for one) proposed a "hidden self" not defined by cultural experience.
3. This empirical, relativistic approach characterized American anthropology in the period 1920–1950.

B. The mid-century saw a turn to a "harder" approach to anthropology.

1. In the 1950s, Leslie White and Julian Steward argued that cultures were materialistic systems, "elaborate thermodynamic systems" in one White metaphor, each possessing an inner structure whose development followed a deterministic order. In their view, cultures determined the behavior of their members; they were not the result of behavioral choices.
2. Followers of White and Steward dismissed the Boas-inspired culture-and-personality school as unscientific and engaged in "ecological anthropological" studies, reflecting a systems interpretation of culture.
3. In the 1960s, a structuralist approach to cultures, championed by Claude Levi-Strauss and adopted enthusiastically by social scientists and literary theorists, extended the systems interpretation, making cultures into networks of relationships.

C. The popularity of structuralism peaked in the 1970s. In its wake, anthropology splintered.

1. Prominent early followers of White and Steward, especially Marshall Sahlins and Clifford Geertz, broke with an impersonal, materialistic interpretation of culture. They argued that a culture could be understood only as a system of symbols whose meanings in the minds of members determined the culture's unity and character. This "humanistic," as opposed to naturalistic, approach to anthropology was embraced in the 1980s and afterwards.
2. Meanwhile, ecological anthropology, with its focus on adaptation, developed along multiple lines in the renewed attempt to apply hard-science concepts and methodologies to the study of culture.
3. The naturalist-humanist division became sufficiently intense to splinter the American Anthropological Association, leading to the creation, on the 100th anniversary of the association in 2002, of the Society for Scientific Anthropology!

IV. Archaeology is, in effect, the material side of anthropology, and it, too, matured as a science in the 20th century, building on 19th-century beginnings.

A. In the course of the century, archaeology went from digging up artifacts (analogous to the phase of documenting primitive peoples in anthropology) to reconstructing lifestyles. In the process, archaeologists developed methodologies for collecting artifacts that would allow for objective dating and comparison.

B. Understandably, given its European-Christian origin, early archaeology focused on biblical and classical themes and on recovering texts and "art" objects. This "natural history" approach to archaeology dominated the period from 1900 through the 1940s.

C. First in the 1940s and more rapidly after 1950, American archaeology shifted from collecting artifacts to explaining cultural development by way of material remains.

1. Developmental sequencing entailed a more intensively technical approach to archaeology, involving instruments and expertise from geology, biology, chemistry, and physics. In turn, the interest in developmental sequencing led to increased interpretation and explanation. Between 1950 and 2000, archaeology moved in the direction of reconstructing lifestyles.
2. The application of technology to archaeology has enabled more precise dating and location of artifacts, as it has raised new questions for anthropology.

D. In 1959, Joseph Caldwell issued a call for a "new American archaeology," keyed to the concepts of ecology and adaptation. By the end of the 20th century, archaeology had become multidisciplinary, collaborative, and focused on cross-cultural interactions and drift as factors responsible for the complexity of societies and culture.

Essential Reading:

Clifford Geertz, *Interpretations of Cultures*.

Marshall Sahlins, *Culture and Practical Reason*.

Bruce Trigger, *A History of Archaeological Thought*.

Supplementary Reading:

Mathew Johnson, *Archaeological Theory: An Introduction*.

Questions to Consider:

1. Are facts and values fundamentally different from one another, and even if they are, why is the study of values so problematic for science?
2. Does cultural interaction imply homogenization, as in the great American "melting pot" metaphor?
3. Is the causal relationship between cultures and their members like the chicken-egg relationship?

Lecture Twenty-Eight
Culture—History

Scope: Is history a branch of the sciences or of the humanities? The legacy of the 19th century was that history, though often used for propagandistic storytelling, was in principle, a science. Early-20th-century historians thus pursued an objective methodology that would describe the way things *really* happened, free of conscious or unconscious ideology, bias, or subjective interpretation. Generations of graduate students were trained in techniques of evidence gathering that would allow them to get behind self-interest and partial perspectives. Between 1910 and 1930, however, a consensus began to grow that the past, distant or recent, is incapable of being "objectively" reconstructed. All history, in this view—including this survey of the sciences in the 20th century—is necessarily interpretive and, thus, a form of storytelling. Once this is recognized, the question arises as to what the principles of interpretation need to be to distinguish history writing from fiction. Stigmatized as a kind of cultural treason in the 1930s, relativism gave way to objective history, only to return in the 1960s, posing deeper challenges than before. Is history incapable of truth as the sciences understand truth? Is the plight of history as interpretation unique to history, or is interpretation, inevitably subjective or, at best, intersubjective, a problem not only for all of the social sciences but even for the so-called "hard" physical sciences?

Outline

I. Is history "scientific"?

A. For Aristotle, history could not be a science because it lacked universality and necessity. The Renaissance humanist founders of modern history, however, put history at the heart of philosophy precisely *because* of its particularity and contingency!

B. In the 17th, 18th, and 19th centuries, the humanists were overcome by the modernists, who reintroduced rationalist philosophy in the guise of materialistic, deterministic science.

C. In the 19th century, history writing reflected the materialistic determinism of the sciences in general, and two models of history emerged.

1. The first model goes back to the influential German philosopher Hegel, who claimed that "true" history revealed the lawful unfolding of a universal plan. Herbert Spencer in the last third of the 19th century and Arnold Toynbee and Oswald Spengler in the early 20th century wrote universalist histories of humanity in this mode.

2. The other model was that of Leopold von Ranke, whose goal for historians was to "describe the way things actually happened." Ranke challenged historians to give the most accurate and "objective" account of the past possible, employing "objective" in a new sense given to it in German scholarship.

D. Interestingly, many American historians misunderstood Ranke, who emphasized the need to find the underlying causes of history. In contrast, at the turn of the 20th century, American historians saw themselves as engaged in a scientific enterprise, which therefore, from the perspective of the historian, had to be ruthlessly impersonal and factual.

1. Charles Beard and Carl Becker were prominent American historians who dismissed disinterested objectivity as a possible methodology for historians.
2. All historical accounts inevitably reflected biases and value judgments, as Beard, in particular, showed in his 1913 book *The Economic History of the U.S. Constitution*, which argued that the Constitution was the product of economic rivalries among the Framers.

E. World War I shattered the putative objectivity of even the most eminent historians.

1. A 1914 manifesto defending Germany's goals and conduct of the war, entitled "To the Civilized World," was signed by almost all leading German intellectuals (Einstein was conspicuous in his refusal to sign) in spite of being blatantly propagandistic and factually wrong.
2. For their part, the overwhelming majority of British and French intellectuals supported their governments in the demonization of Germany and of Germans as an enemy and refused to allow German scholars to participate in conferences for years after the war.
3. In the United States, the situation was much the same, particularly after entry into the war. Many historians (as most academics and intellectuals) supported that involvement. A National Board for Historical Service was formed in 1917 that produced written materials for the public and for schoolteachers to use to promote patriotism and U.S. involvement.

F. What had become of objectivity? The hideous violence of World War I led many to dismiss as a myth the progress promised by a commitment to reason. In 1924, the historian James Harvey Robinson wrote, "I have come to think that no such thing as objective history is possible."

II. Between 1930 and 1960, relativist historiography, that is, history writing that offered a particular interpretation of events, would be seriously challenged, even stigmatized, by world events.

A. With the Great Depression and the rise of totalitarian regimes in Russia, especially after Stalin achieved control in the late 1920s; in Germany with the election of Hitler in 1933; as well as in Italy with Mussolini (1922) and in Spain with Franco (1938), historians had to choose: Are these regimes to be described neutrally or valuationally?

B. In the 1930s, relativism in history writing and more generally was stigmatized as destructive of social hope and solidarity, of a shared sense of right and wrong, and of belief in good and truth.

C. With the outbreak of World War II, pro-war intellectuals attacked relativism as pathological, and Beard, who opposed Roosevelt's intervention and later revealed the means Roosevelt employed to win support for intervention, was a particular target. The historian community overwhelmingly committed itself to the discovery of universal values and objective history writing.

D. After World War II, the German philosopher-historian Leo Strauss at the University of Chicago championed objective political analysis and history writing. In the 1980s, one of his followers, University of Chicago professor Alan Bloom, published *The Closing of the American Mind*, an argument against relativism and an appeal for a return to universal standards and objective value judgments.

E. This intellectual climate of the late 1930s–1950s displaced the relativist position in historiography. Indeed, in the early 1960s, the *International Encyclopedia of the Social Sciences* depicted relativism as no longer viable intellectually.

III. But even as the obituary of relativism was being written, relativism was making a comeback, and with a vengeance.

A. From the 1960s–1980s, history was used as a means to debunk the idea of objective knowledge, including objective knowledge in the physical sciences. History undermined the modernist project, extending back to the 18th-century Enlightenment, that reason is the means by which progress is made.

B. Remember that the 1960s were a flashpoint for anti-establishment protest, spawning movements to demand civil rights, oppose the Vietnam War, protect consumers and the environment, protest the influence of multinational corporations, and so on. These movements assailed science and technology as tools and accomplices of establishment power brokers.

C. An intellectual consensus grew, outside the sciences, that this attack on the modernist program had merit. A crucial role in this critique was played, ironically, by historians of science and technology!
   1. Thomas Kuhn's 1962 *The Structure of Scientific Revolutions* precipitated a shift to externalist histories of science and technology that, over the next 20 years, made a compelling case for the influence of social and cultural forces and values on the conduct of science and technology.
   2. Before Kuhn's work, historians of science and technology practiced internalist history, tracing the technical development of theories or inventions with little reference to their social contexts. Now, the history of both science and technology began to explore the political, economic, and social factors underlying developments in these disciplines.
   3. In the 1970s–1980s, this shift marked the emergence of *post-modernism*: the critique of rationality as the self-evident means by which human beings come into contact with reality and make progress. In this view, reason is seen as an ideological device.
   4. Some externalist history of science had been written in the 1930s, primarily Marxist theories that had limited influence. In addition, in 1936, Robert Merton studied the influence on the Scientific Revolution of religious affiliations among the founding members of the Royal Society of London.

D. History writing, then, became a powerful tool for attacking the status quo.
   1. The French intellectual historian-philosopher Michel Foucault focused attention on power relationships in shaping the ideologies called "knowledge."
   2. The philosopher Jacques Derrida triggered a global craze for *deconstructionism*, a radically relativist assault on meaning and values that sparked the Science Wars of the 1980s–1990s.

E. By the 1980s, however, a growing chorus of voices, including those of historians, was calling for a new, critically defensible concept of objectivity, pointing to the morally corrosive and socially destructive implications of post-modernism, deconstruction, and radical relativism.

Essential Reading:

Peter Novick, *That Noble Dream: The "Objectivity Question" and the American Historical Profession.*

Alain Renaut, *The Era of the Individual: A Contribution to a History of Subjectivity.*

Dorothy Ross, *The Origins of American Social Science.*

Questions to Consider:

1. If history writing is necessarily selective and interpretive, what value is it?
2. George Santayana is famous for saying, "Those who are ignorant of history are condemned to repeat it," but could history ever repeat itself and how would we know it if it did?
3. How can historians reconcile relativism and objectivity?

Lecture Twenty-Nine
Culture—Linguistics

Scope: Linguistics is of special interest for several reasons. In the 20th century, linguistics shifted from a predominantly historical focus (the study of how languages have changed over time), to studying the nature of language as used: its form, function, and acquisition. A particularly influential early-20th-century theory of language was one that described language as a closed system of relationships, analogous to (but completely independent of) the relational interpretation of space, time, matter, and energy in the relativity and quantum theories. Cultural-behavioral and psychological-behavioral theories of language dominated the mid-century, to be supplanted by structural and cognitive theories in the late century.

Outline

I. As we've discussed, one challenge confronting the social sciences as sciences is that they deal with subject matter that incorporates value judgments.

A. A second challenge is achieving methodological objectivity. In studying material that incorporates value judgments, is it possible to take a neutral methodological stance?

B. Anthropologists, political scientists, economists, historians, and sociologists all have these two challenges with which to contend. Archaeologists and linguists, however, would seem to be free of this problem; in this lecture, we turn to the field of linguistics.

II. Modern linguistics began with the work of Ferdinand de Saussure in the first decade of the 20th century. De Saussure influenced many subsequent intellectuals and reoriented the study of language.

A. Eighteenth-century linguistics was interested in the origin of language; 19th-century linguistics was interested in the historical development of language. The 19th-century also saw the origin of a science devoted to collecting and studying languages.

B. Not surprisingly, in the second half of the 19th century, an evolutionary interpretation of the historical development of language became popular. Nineteenth-century linguistics also viewed languages as systems with coherent structures. Just as Georges Cuvier was able to reconstruct extinct creatures from a handful of fossil bones, one could do the same thing with languages.

C. Using this system orientation, de Saussure, as a young man, predicted the existence of a previously unknown vowel form in an extinct

language, and he was subsequently proven correct. In 1906, as a professor at the University of Geneva, de Saussure began teaching a course in general linguistics in which he presented his own, surprisingly radical, theory of language.

1. This theory was published in 1916 by former students from notes after de Saussure's untimely death in 1913. He had set aside *diachronics*, the study of how languages change over time, in favor of *synchronics*, how languages "work" at a given time as they are used. He was particularly interested in the origins of meaning.
2. De Saussure argued that all linguistic meanings and values derive from relationships among the sounds and signs of a language, with no necessary connection at all to what language refers to. For de Saussure, a language is a closed network of relationships.
3. This theory sounds similar to the claim in the general theory of relativity that the mass of an object is a function of the total masses of all the other objects in the universe. In the same way, the meanings and values of a language are a function of internal relationships.

D. For de Saussure, language was a social "fact." This idea echoes that of the French founder of modern sociology, Emile Durkheim, who asserted that social relationships exert forces on the members of society. In the same way, language causes us to behave the way we do linguistically.

1. Therefore, the focus of linguistics was on *semantics*, the meanings of words, as opposed to *syntax*, grammatical rules.
2. These ideas are also similar to those of David Hilbert, with his formalist interpretation of mathematics as a closed system of logical relationships.

III. Contemporaneously with de Saussure, Franz Boas became very influential in linguistics in the United States, because of his relativist culture perspective.

A. Boas pioneered the study of native languages, native North American languages in his case, as opposed to the previous almost exclusive focus on the ancestry and "heirs" of the classical languages, Greek and Latin, primarily. Boas's relativism generated a school of linguistics that studied languages in their particular cultural contexts.

B. Two of Boas's followers, Benjamin Whorf and Edward Sapir, formulated the hypothesis that each language represents a certain way of experiencing the world.

C. Leonard Bloomfield began with Boas but initiated an empirical-behavioral school of linguistics that linked language to behavioral psychology and its methodologies.

D. *Descriptivism*, theory-neutral descriptions of languages and their rule systems, emerged in the 1940s and 1950s as a further development of Bloomfield's empiricist-behavioral approach.

E. Descriptivism, in turn, gave rise to structuralism, that is, the attempt to discover the rules underlying the use of a language, the structural rules that are exemplified in the syntax of a language, rules of which speakers are unconscious even as they "obey" them.

F. From 1925—1950, the Prague school of functional linguistics focused on identifying the network of relationships among the functional elements of a language.

G. Zelig Harris, at the University of Pennsylvania, was a particularly successful and influential proponent of descriptive-structural linguistics into the 1950s. Harris's most enduring impact on linguistics, however, may be his influence on Noam Chomsky, who as a graduate student at Harvard, was also influenced by Roman Jakobson, the most prominent member of the Prague school.

IV. Chomsky synthesized the work of Jakobson and American descriptive-structuralist linguistics.

A. In 1957, Chomsky published *Syntactic Structures*, a small book that transformed the field of linguistics even more quickly and more deeply than de Saussure's book had.

B. Chomsky set aside questions of semantics and de Saussure's "social fact" and focused on syntax as the key to linguistic behavior.

C. His commitment was almost violently anti-behavioral. For Chomsky, language competence cannot be acquired behaviorally, because very young children quickly display an ability to generate an unlimited number of sentences that they have never heard.

D. Chomsky was also anti-Boasian in his insistence that linguistic competence is a universal neurological capability. At a deep level, all languages are, in principle, inter-translatable.

E. Chomsky's search for an absolute linguistic structure gave rise to an extraordinarily prolific and fertile research program that dominated linguistics in the 1960s–1980s.

V. Late-20th-century linguistics has qualified its enthusiasm for Chomsky's approach, and other approaches to understanding language have emerged.

A. Not surprisingly, one of these schools has focused on semantics.

1. De Saussure made a distinction between *parole*, the sounds made by speakers of a language, and *langue*, the underlying, abstract structure of a language.

2. Chomsky made a distinction between *competence*, the neurological capability of speaking, and *performance*, again, the sounds speakers make.

3. A more moderate position emerged in the late 20th century calling for linguistics to focus on how people communicate.

B. George Lakoff and collaborators have developed further the Boas-Sapir-Whorf claim that each language encapsulates a distinctive way of experiencing the world. They explore language's metaphorical character as revealing universal structures of unconscious bodily awareness. This school brings biology, cognitive psychology, and genetics into linguistics.

C. Finally, some linguists have argued for a more comprehensive relational grammar than Chomsky's, in which form, substance, content, and expression are equally weighted parameters of language.

Essential Reading:

Ferdinand de Saussure, *Course in General Linguistics.*

Roy Harris, *Language, Saussure and Wittgenstein: How to Play Games with Words.*

Geoffrey Sampson, *Schools of Linguistics.*

Questions to Consider:

1. If a language is a closed system of relationships, how can it refer to anything outside language?
2. If language as a social fact exerts forces on its speakers, how do speakers cause linguistic change (for example, via slang, metaphors, and so on)?
3. Is translation from one language to another possible for a Boasian? For a Chomskyan?

Lecture Thirty
Society—Sociology

Scope: Sociology is, conceptually at least, subsumed under anthropology and subsumes political science. What is a society? What distinguishes it, what keeps it together over time, what are the laws of its functionality? In the mid-19th century, Auguste Comte invented the term *sociology* as the name of a new science of society, conceived along Baconian-Newtonian lines. Comte, with Marx, John Stuart Mill, Herbert Spencer, and Emile Durkheim, created the core legacy of social and political science that the 20th century inherited, including a deep ambivalence between description and prescription. Twentieth-century sociology moved from grand theories of society to the detailed study of social processes and institutions.

Outline

I. In the course of the 20th century, sociology evolved from a science of grand theories of "society" to a science of social relationships and processes.

   A. The 19th-century legacy of social theory was formidable, including Auguste Comte, Karl Marx and Friedrich Engels, John Stuart Mill, Herbert Spencer, and Emile Durkheim.

      1. Comte invented the term *sociology* and, beginning in the 1820s, formulated a truly grand theory of humanity's cognitive evolution within which his theory of society found its basis.
      2. Comte focused on how the human mind had evolved from its earliest animist beginnings through polytheism, monotheism, and a metaphysical state of mind in the post-medieval world, to the scientific, or *positivist*, state of mind.
      3. Comte's goal was a reason-driven society that balanced order and progress, social statics and dynamics, the former to be anchored in conservative universal religious rituals, the latter to be managed by a council of industrialists and scientists.

   B. Marx and Engels were deeply committed to a materialistic and deterministic theory of society, in which social evolution is driven by unstable forces (greed, private property, and pursuit of self-interest) until society reaches an equilibrium state, called *communism*. After 1859, Marx was strongly influenced by Darwin, to whom he wanted to dedicate *Kapital*, such that society moved by directed evolution to a classless, equilibrium condition.

   C. John Stuart Mill's social theory, consistent with his induction-based philosophy, proposed an empirical search for principles underlying social relationships that exist in society.

   D. Herbert Spencer defended a radically materialistic, deterministic theory of cosmic evolution that incorporated the emergence of man, values, and society.

   E. In retrospect, Emile Durkheim stands out as the first "modern" sociologist.

      1. For Durkheim, *society* was a name for the network of relationships that caused the members of that society to behave in specific ways. Further, a primary objective of every society was to communicate to its members a sense of solidarity.
      2. The 19th century saw society itself as having an abstract existence independent of its concrete manifestation. Durkheim redefined the concept of *society* as a much more concrete entity.
      3. Durkeim's network of relationships can exercise forces on people in subtle ways; notice that this idea is similar to what de Saussure said about language.

II. Twentieth-century sociology extends the Durkheimian approach to sociology without adopting his particular theory.

   A. The first great 20th-century sociologist was the Italian Vilfredo Pareto.

      1. For Pareto, who also wrote extensively on topics in economics and political science, "society" was a name for an aggregate of correlated individuals, each of whom is driven by non-logical, psychological/emotional motives.
      2. Pareto developed a true systems approach to society and the economy (in its modern sense), an approach that was naturalistic and employed a "logico-empirical," that is, inductive, methodology but was not rational in the traditional sense of that term.
      3. Nevertheless, in a manner similar to the kinetic theory of gases, radioactive decay, R. S. Fisher's population genetics, and late-1920s quantum mechanics, Pareto argued that the behavior of a society as a whole can be lawful even if the behavior of each of the individuals making up that whole is not.

   B. Max Weber is perhaps best known for his study of the relationship between Protestantism and the rise of capitalism.

      1. Weber promoted a humanistic, as opposed to a naturalistic, sociology, one in which only individuals act; only individuals, as nodes or atoms of the networked social reality, are "carriers" of value and meaning.
      2. For Weber, all action by individuals is driven either by tradition or by affect, which as for Pareto, is not irrational but is not rational in the philosophical-scientific sense.
      3. Capitalism, for Weber, is a mode of social organization in which the values of efficiency and rationality play a dominant role. Note the highlighting by Weber of efficiency and the characterization of

rationality as a value: modern society places a value on rationality; rationality is not intrinsically valuable.

C. Typically, American social science, which became increasingly influential in the 20th century, was less theory-centered than European social science and more fieldwork-centered.
   1. American pragmatism, developed by John Dewey and others, asserted that human behavior is instrumental; that is, it matches means to ends. Members of society look for effective behaviors in constantly changing environments.
   2. Pragmatism incorporated chance, contingency, novelty, possibility, progress, and freedom into an activist, optimistic philosophy.
   3. Pragmatism offers a process-centered interpretation of experience and, therefore, rejects dichotomous thinking.

III. Although the mid-century saw important European intellectual contributions, American empirical and functional sociology stands out.

A. Just before World War II, the Frankfurt school of social philosophers, transplanted to the United States on the eve of the war, exerted influence on social theory, as did the foundation of sociology of knowledge. Karl Mannheim was a leading figure in applying sociology to knowledge, extending the concept of *ideology* to all forms of knowledge except science and mathematics. As we know, in the 1960s, scientific knowledge would also be identified as ideological.

B. Meanwhile, American academic institutions became deeply committed to a social reform agenda while performing social science research.
   1. The Chicago School of Urban Studies, for example, produced a series of research monographs on poverty, the black ghetto, suicide, immigrant communities, and so on.
   2. Concurrently, the *Yankee City* series edited by W. Lloyd Warner documented social life in a number of northern cities.
   3. Most famously, perhaps, the Lynds produced *Middletown*, a loosely disguised, closely detailed longitudinal social study of a single American industrial town (Muncie, IN) from 1924–1937.

C. Post-World War II sociology continued to move away from grand theories to social process studies.
   1. The first dominant postwar figure in American sociology was Talcott Parsons, who had developed a functionalist approach to sociology: identifying functional elements in a society and the relationships among those elements. This model transformed into a structuralist view in the 1960s–1970s.
   2. In the 1970s–1980s, sociologists and political scientists, perhaps more than any other group of scientists, embraced post-modernism and the associated critique of reason, rationality, and progress. Science and technology were included as part of Mannheim's sociology of knowledge; they, too, were seen as ideologies, not purely neutral descriptions of reality or neutral inventions.
   3. At the end of the 20th century, sociology experienced a methodological fragmentation, analogous to that seen in anthropology, and seemed to be searching for a new disciplinary direction at the turn of the 21st century.

Essential Reading:

Randall Collins, *Four Sociological Traditions: Selected Readings*.

Dorothy Ross, *The Origins of American Social Science*.

Rob Stones, *Key Sociological Thinkers*.

Questions to Consider:

1. In what sense are societies more than the sum of the individuals who comprise them?
2. Do people deliberately choose the ways in which they associate with one another?
3. Is the goal of sociology describing how people, in fact, live together or identifying how they might or ought to live together?

Lecture Thirty-One
Society—Political Science

Scope: Within the broad framework of social theory, political science is concerned with the relationships of power and authority that provide an infrastructure for the functional unity of "a people." Classically focused on "the State" as the source of this unity, in the early 1900s, political scientists began to substitute the government for the state. Especially in America and England, the viability of a pluralistic society under a democracy and/or with a "liberal" government became the dominant political scientific issue from the teens through the 1920s and up to World War II. In the 1950s, pluralist theory gave way to a behavioral conception of political science, but in the late 1960s and early 1970s, behaviorism was overthrown in the rush to affirm a post-modern interpretation of political phenomena. Political science fractured into many at least seemingly different self-conceptions, based on, among other things, game theory, rational choice theory, and voting model analysis.

Outline

I. What is the source of the unity in a society that anchors relationships of power and authority?

  A. In the early 20th century, the dominant concern of political science in Europe was with "the State."

    1. Americans have difficulty fully understanding the term as it was used and thought of by Europeans.

    2. The State embodied the *organic unity* of a people; the ruler was the embodiment of the State and, therefore, the source of all meaning and value, all power and authority.

    3. Even today, after many countries on the Continent have become democratized, their governments remain far more centralized than that of the United States.

    4. Classically, the State is more than just power and authority; it also embodies the ideals and purposes of a society.

    5. America and Great Britain, at the beginning of the 20th century, represent a revolutionary transformation of thinking, with the substitution of elected government for the State.

    6. The government, in American terms, is a negotiated, pragmatic unification of a fragmented population's changing, competing interests. It is not invested with the same authority and meaning as the State.

  B. The European and the American approaches had profoundly different consequences for political theory and institutions.

    1. America, and to some extent Great Britain, has a radically, aggressively pluralistic society, in which formation and pursuit of special interests is legitimated.

    2. Despite the competition of these special interests, the commonality of the United States has somehow survived, even under such stresses as the Great Depression, World War II, the Vietnam War, and so on.

    3. How a collection of competing special interests can achieve enough unity to function effectively became the central issue for political science in the first half of the 20th century.

  C. Toward the end of the second decade of the 20th century, Harold Laski, a progressive political scientist at Harvard University, became a mouthpiece for the positive value of political pluralism: for party politics, the free formation of special interest groups, and for competition among these groups as defining a public interest that is constantly subject to change.

    1. Laski lost his position at Harvard after defending the right of the Boston police to strike in 1919 and moved to Yale, returning to England in 1920, to the London School of Economics*.

    2. Nevertheless, in the 1920s and 1930s, Laski's theory of democratic government based on contending individual wills became a strong influence on such powerful U.S. jurists and legal theorists as Roscoe Pound, Oliver Wendell Holmes, Jr., and Felix Frankfurter, among many others. Holmes, in particular, argued that law is not based on principle; it is based on a negotiated, pragmatic compromise between social circumstances and legal principles.

  D. Concurrently, a core of intellectual elitists rejected the efficacy of pluralistic democracy and advocated the control of public opinion through "white propaganda."

  E. Further, the modern industrial corporation emerged in the 1880s in the United States and, by World War I, dominated the marketplace as a powerful political institution.

    1. Anti-trust legislation was implemented from the 1890s to protect the public unity, but of course, corporations sought ways to circumvent such regulation.

    2. This development led political science to question whether corporate capitalism is compatible with a pluralistic democracy.

    3. C. Wright Mills's *The Power Elites* was a classic 1950s challenge to the robustness of democracy to protect the pursuit of individual self-interests from the pursuit of corporate interests.

  F. In the 1950s and 1960s, political science underwent a behavioral "revolution," shifting its focus to describing how political institutions and political processes actually worked in the "real world." Of particular interest was the question of why American and British political institutions and processes continued to function in the 1930s, under extreme pressure, when almost all the post-World War I liberal governments put in place in Europe had fallen into the hands of ultra-conservative or totalitarian parties.

II. Behaviorism in political science had run its course by the 1970s, as it had in psychology and the social sciences, and political science took yet another turn.

A. Between 1900 and 2000, political science moved from a focus on individual institutions to a focus on the network of political institutions and their functional interrelationships.

1. Institutions now appear as systemic ordering mechanisms, not "atomic" responses to particular problems. Political science adopted a holistic, system-level view of society.

2. This echoed the rise of functionalism in sociology and, again, resulted in a move toward structuralism in the 1980s.

B. The 1990s saw a turn by political scientists to neo-institutionalism, an attempt to apply "harder" techniques borrowed from economics, such as game theory or rational choice theory, to the study of institutions.

1. Neo-institutionalism reflects prevailing ideas that political structures in society never achieve equilibrium. Instead, the goal for the political process is to achieve equilibrium *plateaus* that will always be upset by changes in the environment.

2. This view of the American system as an open-ended, dynamic process echoes Harold Laski's ideas in 1910–1920.

C. At the end of the 20th century, however, as at the beginning, there remained a decisive split between Europe, indeed effectively all of the world, and the United States, where the function of institutions is to impose commonality on individual social atoms with no intrinsic connections to one another.

Essential Reading:

John Dryzek, et al., *Political Science in History: Research Programs and Political Traditions.*

Mark Mazower, *Dark Continent: Europe's Twentieth Century.*

C. Wright Mills, *The Power Elite.*

Questions to Consider:

1. How can a pluralistic democracy survive competition among contending special interests, each pursuing their own good?
2. Is there such a thing as "the public interest" in a pluralistic democracy and how is it defined?

3. What do we gain, practically speaking, from understanding how our political processes and institutions function?

* *Clarification*: Harold Laski spent a year at Yale after leaving Harvard in 1919 and, on returning to England, joined the faculty of the London School of Economics. Laski's university training was at New College, Oxford University.

Lecture Thirty-Two
Society—Economics

Scope: The formulation of general theories of economic behavior that were capable of generating new economic policies was a late-19th /early-20th-century development. The pioneering efforts involved mathematical models of equilibrium in supply-demand relationships, assuming "rational" choices on the parts of suppliers and consumers. In the second half of the century, major developments included the adoption of game theory mathematics, the growth of econometric models enabled by computers, the integration of economics and law, and attacks on the notion of rationality employed in classical economic theory, for example, Herbert Simon's notions of *satisficing* and *bounded rationality*, and Daniel Kahneman's research into the "irrationality" of real behavior, both of these efforts receiving Nobel Award recognition.

Outline

I. Perhaps the greatest accomplishment of economists in the course of the 20th century was to create a new reality; "the economy" has become similar to "the State" in 19th-century Europe that we discussed in the last lecture.

- **A.** Historically, the term *economy* was used to refer to a well-ordered whole; it did not have specifically commercial connotations.
- **B.** In the 20th century, *economics* became a name for the attempt to understand how the commercial relationships in a society can be a well-ordered whole.

II. Like sociology, 20th-century economics is deeply indebted to developments in 19th-century economics.

- **A.** A "marginalist revolution" was precipitated in 1871 by W. Stanley* Jevons in England, Carl Menger in Austria, and Leon Walras in Switzerland, who independently (re)discovered the principle of diminishing marginal utility.
- **B.** These three thinkers were not the inventors of economic theory. Adam Smith, David Ricardo, and John Stuart Mill were probably the leading economic thinkers in the late 18th and early 19th centuries.
  1. They conceptualized the notion of economics as a science, with the goal of discovering the conditions of equilibrium in the commercial structure of a society. *Equilibrium* was the "balanced circulation" of goods and income.
  2. These three men shared the idea that economic values were objective and keyed to real costs, that is, the costs of production.

- **C.** The marginalist revolution was a conceptual one, asserting that economic decisions had a subjective character; in making an economic decision, a prospective purchaser or seller takes into account the principle of diminishing marginal utility.
  1. Further, marginalists argued that the actual costs of any economic decision are opportunity costs.
  2. These subjective factors complicated the attempt to find an equilibrium condition, prompting the marginalists to use more elaborate mathematical models to discover the condition in which supply and demand are balanced, given the principle of diminishing utility.
  3. Jevons made significant contributions to symbolic logic and to probability theory, especially the notion that probabilities were measures of rational expectation.
  4. Walras's goal was discovering stable equilibrium solutions for algebraic supply-and-demand equations, assuming "pure" exchanges (in which supply and demand both derive from utility maximization), in a competitive market.
- **D.** Early-20th-century economics was marked by a dispute between the marginalists and Alfred Marshall, but important ideas were being developed by others that would bear fruit later in the century.
  1. Marshall disapproved of the deductive reasoning employed by the marginalists, favored "real" costs and objective values, and sought to explain how utility-based demand and real cost–based supply interacted in actual markets. This concrete approach dominated British thinking until the 1930s.
  2. Meanwhile, Austrian economic theorist Joseph Schumpeter, a student of the Menger School*, in 1911 identified entrepreneurship and technological innovation as the engines of economic growth, but attracted little attention at the time.
  3. Walras' student and successor Vilfredo Pareto added social optimization to Walras's algebraic equations. According to Pareto, to achieve economic equilibrium, social utility, as well as individual utility, must be part of the equation.
  4. In America, Thorstein Veblen and colleagues sought to understand how social, historical, and institutional factors affected economic change. *Institutionalist economics* was highly influential in the United States for the first decades of the century but virtually disappeared in the 1920s.

III. The dominant figure of mid-20th-century economics was John Maynard Keynes.

- **A.** Keynes was a well-connected Cambridge academic who made economic theory a tool of government policy, in the process inventing macroeconomics.

1. Keynes was a member of the British Versailles delegation and resigned because of his disapproval of its terms. In the early 1920s, he was vocal on a number of public issues in England. In the 1930s, he published a theory of monetary policy that was savaged by his lifelong rival Friedrich Hayek; Keynes responded by forming a research team at Cambridge.
2. In 1936, synthesizing the results of this team's work and his own ideas, Keynes published his epochal *General Theory of Employment, Interest, and Money*, which became, and remained, a blueprint for government management of the economy.
3. Keynes argued that economic stability was a government responsibility, promoting deficit spending to create employment through public works, dismissing fears of budget deficits. His theory explained aggregate economic output and employment as a function of aggregate demand and showed that this would, ideally, lead to a demand-derived equilibrium without unemployment.

B. Keynes's ideas were adopted by governments before and after the war.

1. In 1940, Keynes published an essay, "How to Pay for the War," whose recommendations, compulsory saving and rationing, became Britain's anti-inflation policy, and extended his general theory, which dealt with recession.
2. Though ill, he led the British delegation to Bretton Woods and was instrumental in creating the International Monetary Fund and the World Bank.

C. The London School of Economics and Political Science (LSE) was created in 1895 as a research-plus-teaching institution and, in the 1930s, blossomed as a center of economic theory.

1. Lionel Robbins, who came to LSE as chair of economics in 1932, rejected Marshallian ideas and ushered marginalist economics, through Pareto, into British economic thought. Robbins also brought a number of brilliant, young economists to LSE, who substantially developed Pareto's ideas.
2. Recall that Pareto's thought was keyed to including social optimization, along with individual optimization, in economic decision making. Could economics as a science identify social optimization, when doing so implies a value judgment?
3. One of the most seminal thinkers at LSE and, later, Harvard was Paul Samuelson, who was responsible for bringing extremely sophisticated mathematical techniques into economics in the post-World War II era.

D. At the University of Chicago, Milton Friedman was a lifelong opponent of Keynes, in that he believed economic output is determined by monetary policies, not income-expenditure models.

IV. Behind the grand economic equilibrium-seeking theories of the first half of the century, mathematical tools took center stage in the second half of the century and led to a reconsideration of rationality.

A. In 1943, John von Neumann and Oscar Morgenstern published their *Theory of Games and Economic Behavior*, which formalized choice under risk and uncertainty by providing rules for calculating expected utility.

B. Ironically, in the mid-1950s, Leonard Savage derived the same expected-utility measures using subjective, rather than objective, probabilities, and Kenneth Arrow and Gerard Debreu arrived at the same results without using probabilities at all.

C. The most dramatic conceptual turnabout in economics has been in the last 10 years, with the impact of work begun in the 1970s by Daniel Kahneman and Amos Tversky. They argued on empirical grounds that people are not efficient, "rational" decision makers who are focused on maximizing their utility.

1. Kahneman and Tversky in effect extended Herbert Simon's argument in the 1960s that institutional decision makers displayed *satisficing*, not maximization, under conditions of *bounded rationality*.
2. These theories were supported by studies in the 1990s at three universities using real-time PET brain scans and game-playing to reinforce the view that decision-making is emotional and that people do not know what their best interests are so they cannot be utility maximizers!

D. At the beginning of the 21st century, then, economic theory must adapt itself to the non-rationality of human decision-making.

Essential Reading:

By far the best reference source for the history of economics is the web site *History of Economic Thought* maintained by the New School for Social Research in New York City: www.cepa.newschool.edu/het/

Supplementary Reading:

Robert Skidelsky, *John Maynard Keynes: Fighting for Freedom, 1937–1946*.

Questions to Consider:

1. How can there be a science of economics if decision making is not a rational process?
2. How can economists, as social scientists, identify the values that ought to underlie societal economic policies?
3. In what sense is "the economy" a reality?

* *Clarification*: Joseph Schumpeter was a student of the Menger School and was a middle-aged man when he came to Harvard.

Lecture Thirty-Three

Mind—Classical and Behavioral Psychology

Scope: By the late 19th century, mind was the last bastion of human privilege, the only natural phenomenon not (yet) reduced to deterministic, materialistic processes, but it was under attack. But mid-19th-century neurophysiology laid the foundation for a materialist theory of brain activity and of consciousness itself. At the turn of the 20th century, mind became problematic. On the one hand, the new discipline of experimental psychology was challenging the claim that we knew our minds and clinical psychology was accumulating case studies that reinforced this conclusion. Freudian psychology was built on the claim that most mental processes, and all of our desire-driven actions, were unconscious in origin, and Jung extended the unconscious into history through his concept of the collective unconscious. Concurrently, behaviorism, which dominated the scene from the 1930s to the 1970s, dismissed consciousness as a causally significant factor for explaining human behavior, while Gestalt psychology dismissed behaviorism. After the 1970s, both were supplanted by cognitive psychology.

Outline

I. Philosophers have tried to understand the mind at least since the time of Aristotle, but scientific psychology is a product of the last quarter of the 19th century.

A. Wilhelm Wundt created the first experimental psychology laboratory in 1875 and, in 1895, the first research institute for experimental psychology. As we will see, the evolution of psychology, from the early-20th-century introspective psychology of Freud to the cognitive neuroscience of the 1990s, is a resumption of the experimental agenda that Wundt mapped out.

1. Consciousness, for Wundt, is the reality that is the subject of psychology; his research interests included perception, memory, learning, and reasoning.

2. Wundt's conception of humans was that they are willful and emotional beings, not primarily rational. Reasoning is not the essential characteristic of our nature.

B. Wundt had a considerable influence on the first American to teach experimental psychology, William James, a member of the intellectual circle that created pragmatism. James was also a member of the philosophy faculty at Harvard, but in the late 1880s, changed his faculty identification to psychology.

1. James taught Wundt's ideas in the classroom and hired a student of Wundt's, Hugo Munsterberg, who directed and expanded James's experimental psychology lab at Harvard.
2. In 1890, James's *Principles of Psychology* appeared, introducing the term *stream of consciousness* and adding to Wundt's agenda the phenomenon called *selective attention*. James took the position that consciousness had a systemic or holistic character, reflecting internal organizational principles; it is not just a random collection of inputs from the senses.
3. The research agenda that James mapped out would manifest itself 30 years later as Gestalt psychology.

C. Wundt and James developed one type of introspective psychology that was concerned with how the mind organizes sensory perception so that we experience the world in an organized fashion. Another type of introspective psychology was that of Freud.

1. Freud and his mentor, Josef Breuer, published *Studies in Hysteria* jointly in 1895, but Freud stepped out on his own in 1900 with *The Interpretation of Dreams*. Freud's famous theory of repression emerged from his study of "hysterical" patients. He developed psychoanalysis as a technique for helping patients release repressed material, which according to Freud, is the source of all neurotic and psychotic symptoms.
2. The most important aspect of Freud's thought is his insistence that human behavior is driven by unconscious motives. Thus, the unconscious became the subject of psychology.
3. Freud's "map" of the mind involved the unconscious *id*, seat of the pleasure principle; the conscious (and preconscious) *ego*, seat of the reality principle; and the *superego*, which manifests itself as the conscience and as the ego ideal. Repression and conflict were fundamental features of this internal landscape and, for Freud, the physical manifestations of repression and conflict could always be traced to childhood sexual trauma.

D. Jung was, initially, an enthusiastic Freudian but broke with Freud in 1911, when he began to suspect that he was being groomed as Freud's Christian "mouthpiece."

1. From 1914 to 1927, Jung went through a self-described "dark" period in which he explored his fears, anxieties, fantasies, and dreams.
2. He emerged as an "explorer" of the unconscious, specifically, the *collective unconscious*. This term can be defined as universal patterns for organizing experience that manifest themselves in dreams, visions, mythology, religion (especially mysticism), alchemy, art, and literature.

3. By studying these manifestations of the collective unconscious, we can discover the *archetypes* that all human beings share because of our common biological history. One of these archetypal patterns is called the *self*.

II. Freud and Jung's focus on the unconscious mind stands in contrast to the emphasis of behaviorism.

A. John Watson in 1913 announced his decisive break with all forms of introspection-based psychology, proclaiming that the subject of psychology was not mind or consciousness, but the prediction and control of behavior.

1. Watson was influenced in this by Pavlov's work on conditioned reflexes and Edward Thorndike's 1911 text, *Animal Intelligence*.
2. Thorndike proposed two laws of animal intelligence: Behavior is determined by its consequences, and behavior is reinforced by repetition.
3. Watson was forced to resign from Johns Hopkins in 1921 and joined the J. Walter Thompson advertising agency, successfully applying his academic research.

B. Beginning in the mid-1930s, behaviorism was increasingly identified with the work of B. F. Skinner.

1. Skinner's 1938 *The Behavior of Organisms* revived Watsonian stimulus-response behaviorism on more sophisticated grounds. Skinner emphasized *operant*, or adaptive, conditioning and the importance of schedules of reinforcement.
2. For Skinner, people do not act; they react to the environments in which they find themselves. Mind, body, and personality are of no relevance to psychology, only patterns of reaction to environments, which can be designed to elicit any reaction desired.
3. His controversial 1971 book, *Beyond Freedom and Dignity*, argued that a person's behavior could be adjusted in the same way that NASA adjusts one of its spaceships.

III. Gestalt psychology emerged at the same time as behaviorism and in opposition to it.

A. Gestalt ("form" in German) psychology extended James's notion of how the mind organizes experience. For Gestalt psychologists, conscious experience has a holistic character that reflects innate structuring by the mind: The mind is not a passive receiver of external stimuli but actively organizes and interprets them.

B. Gestalt psychology was founded by Max Wertheimer, Kurt Koffka, and Wolfgang Kohler at Frankfurt in 1910–1914. All three fled the Nazis to the United States and settled at various universities.

C. In the period 1920–1930, the three published seminal works on such subjects as the figure-ground distinction, perception, and recognition of movement.

D. The Gestalt psychologists were interested in selective attention and the fact that selectivity comes from inside the observer. From this point of view, Gestalt psychology was in sharp tension with behaviorism, which asserted that the mind was irrelevant.

E. In the 1930s, Kurt Lewin began his influential Gestalt-based research on group dynamics, conflict, and the "life space" of the self, and Gordon Allport published his Gestalt theory of personality, but behaviorism remained the dominant theory in psychology until the 1960s.

IV. In the 1970s, behavioral psychology was displaced by cognitive psychology, in which mind matters once again!

A. Ulric Neisser's 1967 text, *Cognitive Psychology*, and the founding in 1970 of the *Journal of Cognitive Psychology* heralded a challenge to behaviorism and spawned a new scientific discipline.

B. Cognitive psychology resumes the central role for mind that it had had from Wundt through the Gestalt theorists. Its major themes include memory, learning, and reasoning—all central to Wundt's research program.

C. In the last 25 years of the 20th century, we see a shift toward the scientific study of mind and mental processes, and we now have much more powerful tools with which to study these processes.

1. Functional MRI devices and PET scanners, for example, allow us to observe mental processes in real time.
2. This technology has enabled imaging of the brain as subjects engage in learning, speaking, reasoning, and so on.

D. Some of the discoveries being made in the correlation of brain and mind are disconcerting. For example, research supports the idea that conscious will is an illusion.

E. In our next lecture, we turn to artificial intelligence research and its connections to cognitive psychology.

Essential Reading:

Sigmund Freud, *The Ego and the Id*.

Carl G. Jung, *Archetypes and the Collective Unconscious*.

B. F. Skinner, *Beyond Freedom and Dignity*.

Daniel N. Robinson, *An Intellectual History of Psychology*.

Questions to Consider:

1. What was the appeal of behaviorism that it rose to dominance and remained dominant for decades in spite of denying that mind mattered?
2. If consciousness turns out to be a merely superficial phenomenon, in what sense is cognitive science an advance over Freud and Jung?
3. How did Freudianism, in which our actions are driven by unconscious, barely controllable drives, prove so powerful a cultural influence for the first two-thirds of the 20th century?

Lecture Thirty-Four
Mind—Cybernetics, AI, Connectionism

Scope: The idea that thinking is a deterministic physical process is an old one, already present in the 17th century. But in the 1940s, with the convergence of the new science Norbert Wiener called *cybernetics*, the realization of Alan Turing's conceptual computer, and the McCulloch-Pitts model of the neuron, this idea became a *scientific* idea. Inevitably, the mind was modeled as a computing machine and, thus, as an information-processing "device." Early work by Simon and Newell and by Minsky and Papert suggested that a thinking machine could be built based on a Turing computer, dismissing an alternative approach named *neural nets*. These two approaches reflect profoundly different conceptions of thinking and of rationality. Meanwhile, ever-more powerful experimental equipment allowed identifying increasingly specific correlations between mind and brain. By the end of the century, ironically perhaps, evidence was mounting that the initiation of action preceded conscious willing, which, if validated, would make consciousness at best only indirectly relevant to a causal theory of behavior and, perhaps, irrelevant after all!

Outline

I. In the last lecture, we discussed the strands out of which cognitive psychology was woven, including the work of Wundt and James and the Gestalt psychologists. Another major influence that led to cognitive psychology and its expansion into the broader field of cognitive science is the field of artificial intelligence (AI), which is itself closely tied to *cybernetics* (machine control theory).

A. Between 1942 and 1952, the Josiah Macy Foundation sponsored a series of conferences that, inadvertently, brought AI into being.

1. The foundation's goals were to identify the behavioral changes that would prevent future wars, and to that end, a broad spectrum of thinkers was brought together to "brainstorm" for a few days.
2. The foundation's agenda was co-opted by scientists with innovative ideas for how the mind works, how the brain can be modeled, and how human-like behavior can be demonstrated in machines.

B. From the start, the conference series was astonishingly rich in innovative theories.

1. Warren McCulloch, a biologist who chaired all 10 meetings, and his collaborator Walter Pitts, an electrical engineer, presented a binary electrical model of the neuron and of neuronal networks that could mimic the way in which the nervous system seemed to function. A mathematician conference participant, Lorente de No,

commented that the human nervous system might be interpreted as a kind of computing machine.
2. At the same meeting, John von Neumann gave a presentation on the electronic digital computer, having accidentally learned of the ENIAC project at the University of Pennsylvania. He also described Alan Turing's work and predicted that a computer could be built to solve any mathematical problem for which it was given an algorithm.
3. Norbert Wiener described how machines with feedback circuits and homeostasis, discussed at the conference by Arturo Rosenblueth, displayed adaptivity and apparently purposive behavior, implying that human purposive behavior was just an example of feedback processes in a more complex system.
4. In 1943, Alan Turing published *Machine Intelligence*, which further advanced the idea that human reasoning is a form of computing and, therefore, a computer could be said to reason.

C. Especially in the period 1946–1948, these conferences served to promote mutually reinforcing and productive interactions among the participants.

1. Between 1946 and 1948, Wiener developed his cybernetic theory of how feedback loops could be used to adjust the behavior of machines.
2. Wiener linked cybernetics to the emerging theory of information that Claude Shannon and Warren Weaver were developing in the mid-1940s.
3. In 1948, Shannon and Weaver showed that electrical circuits could implement the rules of propositional logic, creating the central design tool for electronic computers that is still used today. At the same time, McCulloch showed that his neural network models could perform these operations as well and, by incorporating feedback, could display memory (and later, learning).
4. In 1948, von Neumann oversaw construction at Princeton of EDVAC, the first stored-program computer. EDVAC's serial algorithmic software architecture became the de facto standard for virtually all digital electronic computers into the 21st century.
5. The alternative to the von Neumann architecture was the McCulloch-Pitts neural net architecture, to which we will return.

II. In 1956, the pioneer computer scientist John McCarthy convened a conference at Dartmouth University and coined the term *artificial intelligence* as its theme.

A. The implementation of computer programs that could "reason" was already underway by 1956.

1. In 1952, Arthur Samuel at IBM began a 10-year-long development of computer programs that could play checkers, eventually at world-championship levels.
2. In 1955, Herbert Simon and Alan Newell published a program called "Logic Theorist"; they followed this up in 1957 with "General Problem Solver", which could solve a wider range of problems.

B. In 1963, the Defense Advanced Research Projects Agency (DARPA) gave MIT a grant to pursue machine-aided cognition research, and the rate of development accelerated.

1. The MIT AI Lab was created, and Marvin Minsky emerged as a leader of the *top-down approach* to AI, in which mind is interpreted as computing with symbolic representations.
2. In short order, "smart" software appeared, based first on the "microworld" concept and, from 1975, on what Minsky called *frames* (knowledge representation schemes). One example of these software programs was "SHRDLU", which enabled a computer to manipulate blocks according to instructions.
3. In 1975, "meta-DENDRAL" was the first program to make a scientific discovery. In 1974, "MYCIN", the first expert system program, was demonstrated and, in 1979, extended to a commercial product, the same year that "INTERNIST", the first medical diagnostic program, was published.

C. Between 1970 and the early 1980s, the accomplishments of the MIT AI Lab reinforced the validity of Minsky's top-down approach.

1. To forestall the potential of infighting about this approach, Minsky and a colleague, Seymour Papert, published a devastating critique of the McCulloch-Pitts neural nets in 1969.
2. In 1959–1960, a Cornell University professor, Frank Rosenblatt, had built a computer, the Perceptron, that implemented the McCulloch-Pitts neural net. Minsky and Papert asserted that such a machine could never solve more than the most primitive kind of logic problems.
3. As a result, neural net development stopped until the mid-1980s.

D. Despite the flood of AI programs in the 1970s and early 1980s, however, top-down AI seemed to become stagnant.

1. The exponential increase in computer power from the mid-1970s masked the weakness of the mind-as-symbolic computer approach. Programming enough real-world knowledge into a computer to make functionally human-like reasoning possible began to seem overwhelming.
2. Meanwhile, in the mid-1980s, Rosenblatt's Perceptron was rehabilitated, the Minsky-Papert critique was rebutted, and the neural net approach to AI took on new life.

3. The neural net, or *bottom-up approach*, is fundamentally different conceptually from the top-down approach: Neural net programs are not algorithmic; knowledge and memory are stored in the connections between "neuron" nodes, not in symbolic form; information storage is distributed throughout the net; and nets display true learning by modifying the weights of their internal connections in order to achieve the desired output.

III. The combination of AI research, the cybernetics movement, the maturation of computer technologies, and the application of these technologies to the study of mind returns us to the question: What is the mind?

A. In 1875, when Wundt began the study of experimental psychology, and through the period of Freud and Jung, no one would have doubted the reality of the mind.

B. Behaviorism challenged the relevance of the mind but was replaced with cognitive psychology, in which mind does matter.

C. Ironically, in cognitive science, we are now developing tools that increasingly suggest that what we call "the mind" is a network of physical and chemical activation patterns in the brain.

1. We are beginning to identify localized functioning in the brain. For example, the prefrontal cortex seems to be the origin of decision making.
2. Further, the brain can be electrically stimulated to duplicate experience. The DARPA-funded RoboRat and RoboMonkey showed that brain signals can be intercepted and used to control complex behaviors.
3. There are approximately 10 billion neurons in the brain, and each of these has approximately 10,000 connections on average. Is what we call the mind "merely" activation patterns in an extremely complex network?

Essential Reading:

Howard Gardner, *The Mind's New Science: A History of the Cognitive Revolution.*

Elkhonon Goldberg, *The Executive Brain: Frontal Lobes and the Civilized Mind.*

Steve Heims, *The Cybernetics Group.*

Supplementary Reading:

Rita Carter, *Mapping the Mind.*

Daniel Wegner, *The Illusion of Conscious Will.*

Questions to Consider:

1. Do machines display truly purposive behavior? Alternatively, what is there in human behavior that is more purposive than cybernetic machines display?
2. How is consciousness more than nervous system structure and programming, hard-wired and experiential?
3. Is artificial human-like conscious intelligence possible?

Lecture Thirty-Five
Looking Back

Scope: Looking back over the past 34 lectures, what are the central, new ideas of 20th-century science? Perhaps the most outstanding intellectual development cutting across the sciences has been the cluster of ideas associated with relational, systemic, and holistic thinking. The concepts of emergence and self-organization, the attention this has focused on nonequilibrium states, and the coordinate reassessment of control resulting from the development of neural networks are collateral ideas distinctive of late-20th-century science. The ideas associated with computer science and information theory; the emergence of self-consciousness in the practice of science and its implications for rethinking what we mean by knowledge, reality, truth, and objectivity; and recognition of the need for collaborative interdisciplinarity to do justice to natural phenomena in their full complexity are major intellectual innovations.

Outline

I. In this lecture, I would like to share six provocative thoughts that can be abstracted from our survey of 20th-century science.

   A. First, the scope, explanatory/predictive power, and applicability of science and scientific theories have progressively increased since the 17th century.

      1. This progress has not been linear. It was greater in the 19th century than in the 18th, and the rate of increase in scope and power accelerated throughout the 20th century, continuing into the 21st.
      2. Social factors have been major contributors to this acceleration, including the expansion of externally funded university-based scientific research and the career paths that opened in the sciences for large numbers of people. The sheer number of scientists working throughout the 20th century and into the 21st has contributed to the acceleration of scientific progress.
      3. The extraordinary increase in public and private funding of scientific research is another contributor to this rate of acceleration along with the increasing dependence of industry on science-based innovation for growth and competitiveness.
      4. Finally, a more subtle factor contributing to accelerated growth in scientific knowledge is the feedback into the research process of public and professional expectations: Science has been institutionalized such that scientists are expected to generate new knowledge and are rewarded for doing so.

B. Second, though it is real progress, progress in scope and explanatory/descriptive power does *not* entail progress toward a definitively true account of (physical and social) reality.

1. What we think there is "out there" when we use such terms as *atom*, *space*, *time*, *matter*, *universe*, *Earth*, *economy*, and *language* is, in fact, fundamentally different in 2000 from what we thought they meant in 1900.
2. The inescapable lesson of history is that it is extremely unlikely that such changes have ended and that in 2100, we will still mean the same thing by these terms that we mean today.
3. Further, it is not just science that has changed. Because science gives us an account of reality, we can say that *reality* has changed in the last 100 years.

II. Third, let's turn to seminal ideas within 20th century science that cut across disciplines and, thus, suggest a generic shift in intellectual approach.

A. It will come as no surprise that I call attention, first, to the idea of relationships.

1. More accurately, I call attention to the cluster of ideas associated with the correlated concepts of network, structure, and relationship. These three ideas represent a new way of conceptualizing a wide range of realities.
2. In the course of the 20th century, space, time, matter, energy, language, culture, society, history, and the economy have all been interpreted as continually changing networks of relationships with properties that are a function of the character of those relationships.
3. Networks are relationship structures with properties that are a function of their structure, not of their nodes. This is as true of genes and proteins within the cell as it is of galactic clusters, as it is of the Internet!

B. Another seminal, cross-disciplinary idea is the concept of system.

1. The system idea attributes a holistic character to phenomena. To understand a system you must understand how its parts are mutually adapted to function in that whole. This requires a top-down conceptualization of phenomena, not a bottom-up construction out of elements indifferent to their mutual adaptation.
2. Holism, in turn, implies *emergence*, popularly: "the whole is greater than the sum of its part." That is, systems have properties that do not exist at the level of the individual elements of the system. For example, neither sodium nor chlorine alone has anything like the properties of salt.
3. Emergence has been understood only slowly and under considerable resistance, because the classical tradition held that the world could be built up out of fundamental building blocks in a bottom-up process.

C. Of course, we must also note the idea of dynamism that we have seen throughout this course—change is the norm.

1. Natural and social systems are maintained in nonequilibrium states by energy inputs. Further, such systems often spontaneously organize themselves into complex structures.
2. Nanotechnology research, for example, has revealed that under certain conditions, atoms and molecules will automatically organize themselves into carbon nanotubes or buckyballs.

III. Returning to our six provocative thoughts about 20th-century science, the fourth idea relates to complexity.

A. Herbert Simon once defined a complex system as one whose behavior is unpredictable. For example, computer programs that are more than about 100,000 lines long exhibit fundamentally unpredictable behaviors (though quite short programs can, too). As we become increasingly interested in creating complex systems to take advantage of spontaneous self-organization, as in biotechnology, we are certain to see unpredictable results.

B. Fifth, the relationship between scientific theorizing and instrument technologies intensified in the course of the century to an unprecedented degree. What we claim to know is increasingly a function of how we come to know it using knowledge-intensive artifacts.

1. This process also works in reverse at times. Theories may stimulate the development of new technologies, as we saw with quantum theory and the invention of semiconductors, the transistor, and the laser.
2. We should also note that social needs may have a relationship to technology, but rarely do they have a relationship to theories.

C. Sixth, the 20th century has seen a shift away from "substance" explanations to a focus on processes and relationships.

1. This suggests that we are maturing away from what John Dewey categorized as dichotomous thinking.
2. Must we choose between top-down AI or bottom-up neural networks? Must we characterize phenomena as either matter or energy, either particle or wave? Such dichotomies can often be misleading in the attempt to describe reality.

D. Finally, at the end of the 20th century and the beginning of the 21st, we should note the increasingly collaborative and cross-disciplinary nature of science, expressive of intellectual networking and the growing ability of science to deal with phenomena with minimal idealization.

Essential Reading:

Albert-Laszlo Barabasi, *Linked: How Everything Is Connected to Everything Else and What It Means for Business, Science, and Everyday Life.*

Mark C. Taylor, *The Moment of Complexity: Emerging Network Culture.*

Questions to Consider:

1. Science was obviously more powerful in 2000 than in 1900, but has it strengthened its position as the sole source of truth for society?
2. How can relational structures and information be the ultimate realities?
3. Can science retain its claim to "purity" given its 20th-century relationships to society, industry, and government?

Lecture Thirty-Six

Looking Around and Looking Ahead

Scope: Where are the sciences headed? What are the directions that are plotted for development over the next decade in the sciences and in technoscience, and what are the likely implications for science of globalization?

Outline

I. In a dynamic, nonequilibrium environment, forecasting can be treacherous and prediction downright foolhardy, but we may be able to see some directions that science will take in the 21st century.

A. One branch of science that seems likely to change is astrophysics, with the "discovery" of *dark energy*.

1. As we discussed in past lectures, some force seems to be at work in accelerating the expansion of the universe.
2. This force seems to have manifested itself when the universe was about 7 billion years old. Before that, it may have been masked by gravity.
3. Since 1998, there has been a steady accumulation of evidence supporting the reality of this acceleration.
4. Recall that, in 1900, Lord Kelvin announced that science seemed to be approaching a definitive account of nature. Two "small clouds" remained: the inability to explain the blackbody radiation problem and the inability to measure the speed of the Earth relative to absolute space. Resolving these problems led to quantum mechanics and relativity theory, which totally transformed physics as it was in 1900.
5. Dark energy may be a similar "small cloud" that will require a fundamental change in gravitational theory.

B. Recent observations tell astronomers that galactic clusters existed when the universe was less than 3 billion years old, at a time when, according to inflation theory, the universe could not have had that much structure. This is another question facing astrophysics.

C. Still another challenge relates to whether we are reading the microwave background radiation correctly, which is the basis for much of our current understanding of the structure of the universe.

D. The Standard Model in physics, that is, the unification of electro-weak theory and QCD, continues to be plagued in the 21st century by a poor fit with having to assign mass to neutrinos. Also hovering over the Standard Model is the specter of the Higgs boson, which should be detected when CERN goes back online in a few years. Finding it will strongly reinforce the radical conception that mass is an energy phenomenon.

E. Confirming gravity waves will reinforce pursuit of a quantum theory of gravity. Even more dramatic, however, would be a breakthrough in the information structure theory of the universe.

II. Twenty-first-century science will also see increasing involvement in biotechnology.

A. It is fairly obvious that we are only beginning to understand genetics and the wider processes of intra- and inter-cellular signaling, as well as regulatory and monitoring networks that affect cellular metabolism. The action of genes is actually far more complex than we believed to be the case in the 1960s.

B. It seems inevitable that medicine in 2000 will be judged in 2100 to be as pitifully powerless as medicine in 1900 was judged to be in 2000. Think a bit about the implications of that.

III. The direction of social science research is harder to foresee.

A. One of the most puzzling findings of anthropology and archaeology is the acceleration of cultural development among *Homo sapiens* starting approximately 12,000 years ago, which included organized settlements, long-distance trade, communal production, structures of authority, and social order. Perhaps the 21st century will shed some light on our own cultural evolution in this regard.

B. The assault on consciousness via brain-mind correlation studies, molecular neuroscience, and various approaches to AI is sure to accelerate. We do not yet grasp the implications of *naturalizing* consciousness. When consciousness is reduced to a structural phenomenon that we can model in a machine, what will be left for our self-image?

1. In the course of 300-year history of modern science, our biological existence has been naturalized. Our bodies have been reduced to physical and chemical processes, but throughout the 19th century, when this naturalization was taking place, the assumption was that our consciousness set us apart from other organisms.
2. Freud represented an early foray into the elimination of that privileged characteristic by emphasizing the unconscious. Since Freud, scientists have attempted to gain an understanding of consciousness, primarily by reducing it to a physical phenomenon.
3. What happens if we discover that *mind* is nothing more than an emergent property of a particular kind of network structure?

IV. We are already committed to creating technological innovations based on self-organized, complex systems, which by definition, have unpredictable characteristics. We should be forewarned that these new technologies will surprise us because complex systems are unpredictable, and these surprises will not all be pleasant!

V. The science-technology-society relationship now seems irreversible.

A. Science has definitively lost its innocence. It can no longer claim to generate value-neutral, objective knowledge. The pursuit of scientific knowledge is firmly embedded in social institutions and expectations.

B. Science has been the recipient of public funding and support, because the public perceives that science is a source of technological benefit. If, however, we experience calamities in the 21st century that can be traced to technologies enabled by science, as many believe we will, science will suffer a backlash.

C. We have seen that physical scientists are moving toward the goal of unifying the four fundamental forces of nature: the strong force, the weak force, the gravitational force, and the electromagnetic force.

1. However, science in the 21st century may itself be caught up in a growing cultural unification.
2. Scientific theories are beginning to unify philosophy, metaphysics, theology, and science. They are reaching such a degree of complexity, sophistication, and intellectual power that they touch on questions that were previously reserved for religion and philosophy.

D. The Olympics are a mosaic of the physical capabilities of human beings. In the same way, the sciences are a mosaic of our cognitive response to experience.

1. But science is not merely a cognitive response to experience. Our survey of the history of science in the 20th century should have given us some insight into an interesting methodological practice of scientists: *bricolage*.
2. *Bricolage* involves creating a work of art out of materials found lying about, selectively incorporating these ordinary materials into a work of art.
3. What we have seen of the evolution of the physical and life sciences is just such a selective, opportunistic employment of ideas and techniques "lying about" as a result of apparently unrelated work by others.
4. It is suggestive, then, that behind its formidable technicality, science is as aesthetic as it is intellectual, and I hope that this survey has helped to illuminate some of the intellectual riches of 20th-century scientific theory.

Essential Reading:

John Brockman, *The Next Fifty Years: Science in the First Half of the 21st Century*.

Philip Kitcher, *Science, Truth and Democracy.*

Martin Rees, *Our Final Hour: A Scientist's Warning: How Terror, Error, and Environmental Disaster Threaten Humankind's Future in This Century—On Earth and Beyond.*

Supplementary Reading:

Gunther Stent, *The Coming of the Golden Age: An End to Progress.*

Questions to Consider:

1. If planned experiments and current research lead to a successful quantum theory of gravity and the unification of the four fundamental forces of physical science, is science over, except for details and applications?
2. Is a global science emerging or a globalization of Western science, and what difference would that make?
3. Are biotechnology, nanotechnology, and AI/robotics laying the groundwork for 21st-century calamities more damaging than we will be able to control?

Bibliography

I am indebted primarily to the books in the Bibliography, and especially to the Recommended Readings, for much of the factual material in these lectures; the selection and integration of this material is my own and my responsibility.

Aczel, Amir. *Entanglement: The Greatest Mystery in Physics.* New York: Plume, 2003. A popular but substantial account of the experiment that proved Bohr was right and Einstein wrong about how truly radical quantum reality is.

Allen, Garland. *Life Science in the Twentieth Century.* Cambridge: Cambridge University Press, 1978. No longer in print but easily found. A fine history of the first half of the 20th century and one volume in an excellent series.

Alvarez, Luis. *Alvarez: Adventures of a Physicist.* New York: Basic Books, 1989. Witty, easy-to-read autobiography by one of the most accomplished physicists of the century and one of the least well-known. Out of print but well worth tracking down.

Ball, Philip. *Designing the Molecular World.* Princeton: Princeton University Press, 1996. Very good description of how chemistry, influenced by late 20th century physics, is creating new kinds of materials.

Barabasi, Albert-Laszlo. *Linked: How Everything Is Connected to Everything Else and What It Means for Business, Science, and Everyday Life.* New York: Plume, 2003. A well-written, easy-to-read popular description of networks and networking.

Biagioli, Mario. *The Science Studies Reader.* London: Routledge, 1999. An excellent collection of readings on the mutual relations of science and society.

Bowler, Peter J. *The Earth Encompassed: A History of the Environmental Sciences.* New York: Norton, 2000. An environmental history of the 20th century.

Brockman, John. *The Next Fifty Years: Science in the First Half of the Twenty-First Century.* New York: Vintage, 2002. A stimulating collection of essays by scientists about likely directions of research in the next 50 years.

Carson, Rachel. *Silent Spring.* Boston: Houghton Mifflin, 1962. It is not too much of an exaggeration to say that this is the book that energized the environmental movement in the 1960s, leading to the banning of DDT, the creation of the EPA, and passage of clean air and water acts.

Carter, Rita. *Mapping the Mind.* Berkeley: University of California Press, 2000. An extraordinarily accessible account of the structure of the brain and its relation to mind: popular cognitive neuroscience at its best.

Casti, John L. *Five Golden Rules: Great Theories of 20th-Century Mathematics—and Why They Matter.* New York: Wiley, 1997. Lively popular account of five major 20th-century mathematical ideas and why we should know about them.