Notes on the lectures:
Highlights in blue
Science wars: What Scientists Know and How They Know It
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24 Lectures

Lecture 1 Knowledge and Truth are Age Old Problems

In the 1950's -60's, there was broad hostility of science on political, intellectual and religious grounds. In the 1960's, a number of books written by members of the scientific community who had become interested in the history and philosophy of science concluded that the historical record made it clear that scientific knowledge incorporates judgments that are not strictly logical or factual. Scientific theories are not unique accounts of reality, they do not converge on a "correct" description of reality, but in fact are interpretations of experience.

Concurrently, French intellectuals, especially Michal Foucault and Jacques Derrida
launched an even broader critique on the concepts of knowledge and objectivity in general, claiming all such concepts are historical and ideological and reflect certain perspectives on experience, and in particular the perspectives of the experience of the dominant class of society at a given time.
Ideas such as objectivity, knowledge and truth are in fact the result of cultural prejudices.

The convergence of these two views led to what Goldman calls post modernism of 1980s: (all things are relative). Postmodernists rejected the idea that reason is objective, value neutral, and is the universal means by which human beings can reach truth can resolve problems and improve the human condition.

These three trends Led to the science wars of the 1990s.
How does all this square with broad public support, and increasing role of science in western culture?

Goldman Argues that these science wars are the symptom of a much deeper conflict within science; that they reflect an ambivalence of what the objective of science is, which has persisted for 400 years.
He argues that the problem of what knowledge means within science is imbedded in the 2400 year old war in western philosophy over the meaning of knowledge, truth, reason, and reality.

Plato: wrote about the battle between the gods and earth giants; the gods represented knowledge as absolute. Plato pointed to a body of knowledge that exemplified universal necessary certain knowledge: mathematics.

How ? by using deductive reasoning: if the premises is true the result is true.

[note: Kurt Godel has also demonstrated that even the formalism of mathematics is "incomplete."]

The earth giants represented the "sophists" who were concerned with action and practicality; knowledge referred to a species of belief.
Knowledge has a certain context within which it is true (this is like post modernism)
Dominant strain is Plato and the gods.

This battle was internalized within science at beginning. Wanted it to be both ways; want it to be universal necessary certain, but also want it to be based on experience. So today we have the theory and the lab experiment.
Reality is beyond experience

Lecture 2: competing visions of the scientific method

“modern science” inherited several principles from the medieval period natural philosophy:

1) the task of natural philosophy is to explain natural phenomenon in terms of natural causes
2) knowledge of nature must be gained by direct experience or experiment
3) mathematics is a useful language in studying natural science

Math used in renaissance:
Perspective based on math

Founders of modern science:
Francis Bacon: established methodology of modern scientific method: iterative hypothesis and testing
emphasized importance of experience over mind
use of inductive reasoning; not an emphasis on math

Rene Descartes: deduction important; math important
emphasized importance of mind over experience
have intuitive power to recognize truth
by using induction and deduction can form universal hypothesis from which the particulars of experience could be deduced.
Math primary; experiments of less important
Would “feign” hypothesis

Newton made fun of this

These early scientists recognized a problem:

A type of reasoning called affirming the consequent:
If my theory predicts a certain outcome, and the outcome occurs, this proves my theory
This is a flaw in reasoning: there may be other reasons why the outcome occurs.

Just because an experiment turns out a certain way does not mean a particular hypothesis is correct,
Yet this flawed reasoning is at the core of modern science.
precluded certainty: One can never be sure that because a theory “works” that it is true.

Lecture 3: Galileo, the Church, and Truth

Galileo’s scientific method was different from Bacon and Descartes
Galileo adapted the views of Archimedes: modern mathematical physics manifests itself for first time.
“Nature is a book and the language of the book is mathematics”;
Goes back to Pythagoreans: math is essence of reality.
Galileo is the father of “thought experiment”

“Demonstration” in 17th-18th century: deductive logical proof

Show that what you claim follows.
Used experiments as probes to discover the fundamental processes of nature

The issue between Galileo and the Church is the "truth" of the heliocentric universe:
The Church told him, as long as you teach your theory as a math tool; the best method for calculating positions of planets, calendar dates, etc, no problem. Galileo: argued not only did it work, it was "true".

A number of empirical observations argued against the Copernican or heliocentric theory.
It was not at all clear that the heliocentric hypothesis was true.

Tycho had his own theory, for which no experimental evidence could distinguish it from the Copernican theory. Galileo ignored Tycho's theory. Galileo also ignored the discoveries of Johannes Kepler, that the orbits of the planets were not perfect circles, but ellipses.

The church had a point: how did Galileo KNOW it was true?

Galileo: we can use reason to correct experience; but if experience is untrustworthy, what is the standard by which we correct it? Do we have access to reality independent from experience? No.

So: scientific reasoning always proceeds on the basis of assumptions. You assume what you believe to be true.

There are two methods or philosophies of science: archeological method: uncovering, not interpreting nature;
The contrasting view is that science construes(interprets) experience based on a set of rules.

Lecture 4: Newton's Theory of the Universe

Newton was perceived as revealing fundamental truths about (universal) reality
Newton's laws: were not perceived as an interpretation of experience.
Goal of natural philosopher is to reveal true causes

Kepler's laws are also contrary to our experience.
Newton: clear method and axioms.

Need to know how to interpret the out put of instruments.
Newton: believed in action at a distance. Continental scientists believed this was a return to spiritualism; Leibnitz agreed Newton's equations worked, but did not know what that meant, and Newton backed off. Leibnitz does not know what gravity "is". Leibnitz forced out into the open a feature of science, which is that a mathematical theory of experience can work without our understanding of what is behind that experience. You can take experience to be reality; you can Work with theory as opposed to understanding reality.

Newton believed that reality was material objects moving thru space exerting forces on one another;

Leibnitz believed that reality was an energy network; a network of relationships. Relationships key to reality, not things.

Ironically Both Leibnitz and Newton were on side of the gods. Both were religious, but their work led to a period of denial of god.

Lecture 5 Science vs Philosophy in the 17th Century

Deductive reasoning, as in Euclid's geometry, is only way we can know truth

Thomas Hobbs: how can you discover theories using machines that themselves have theories imbedded in them?

Bacon: emphasis on method
Hobbs: scientific knowledge is the result of a collective effort which is then claimed universal
The collective can be distorted

Lecture 6 Lock, Hume, and the Path to Skepticism

What did the 17th century founder of science know in the universal sense? Nothing,
But were perceived as generating knowledge of nature. That perception drove philosophers to formulate theories of knowledge which were suitable as a foundation for modern scientific knowledge of nature. These philosophies would explain how it was possible for nature philosophers to generate knowledge of nature. Empiricism philosophy: John Lock, George Berkeley, and David Hume
Idealism : Kant
Locke: Essay on human understanding written under the assumption that Newton had made a major breakthrough in achieving knowledge of nature in his Principia.
Lock's theory of knowledge opposes Descartes', as Newton's theory of science contrasts with Descartes.
Descartes: knowledge innate
Lock: all knowledge comes from world; mind blank slate; nature writes on the slate
So knowledge is particular; if particular, how do we find the way to universal truth?
Lock's empiricism: knowledge is a relationship among our ideas; the agreement or disagreement of some collection of ideas. (remember Leibnitz: reality is a series of relationships)
But: our ideas include direct input from the world in terms of primary sensations
Descartes: secondary sensations: color taste smell: all produced by our sensory apparatus
Primary: size motion shape: really do belong to what is "out there"
They have powers to act on our senses to produce secondary sensations
By focusing on the primary, we are able to relate to facts about the real world.
Can be seduced by secondary sensations

Lock admitted we cannot achieve certainty in universal knowledge
But certain enough, so empiricism can't deliver universal knowledge

George Berkeley: explained scientific knowledge without referring to matter.
Launched serious critique of matter: said study of matter is a metaphysical concept
There is no matter independent of attributes

Hume: is not debunking natural science. What he was attacking was notion that Newton, etc. were giving us universal knowledge. As Berkeley said of matter, causality is not a fact out there; it is an idea in us.
We cannot have knowledge of matters of fact. We can have knowledge of our own ideas.

When we make up the rules, we can have knowledge; we can't have knowledge about what is out there; ie universal. Empiricism slides into skepticism; can have probably knowledge;
Found problem with inductive reasoning which has yet to be answered:
What gives us the right to assume that the experiences we have had in the past will continue in the future?
By "cause" is meant necessary and sufficient; for us, it is that something follows something else; we have no knowledge of it's necessity or sufficiency.

Exposed flaw that Lock left hanging

Kant will defend Newtonian science as universal

Lecture 7: Kant restores certainty

The perceived failure of empiricism, since it slides into the skepticism of Hume, led Kant to formulate a school of Idealism to provide a foundation for modern science. Kant was committed to the universal truth of Newtonian physics. Kant was thought of as a physicist. The nebular hypothesis which Kant advocated, was based on the gravity of Newton.

[There is evidence that the nebular hypothesis was first proposed in 1734 by Emanuel Swedenborg]

Kant knows his conclusion: that absolute certain knowledge is possible; he needs to get a theory that supports this.

The Critique of pure reason 1871: performed a Copernican revolution on knowledge in general:
Old view: knowledge results when mind takes in information from the senses; experience is neutral
His view: experience is constructed by mind: mind has a self activity that determines how we experience the world; the mind and experience are not neutral. Mind had intrinsic structure so that experience is the result of the mind's transformation of whatever it is that the world out there does to us. The rules that the mind follows are universal and certain and timeless and necessary. We experience space in terms of Euclidian geometry because that's the way our senses respond to what is out there. Mathematics is the name for the way our senses pre-consciously structure what ever is out there so that it appears in spatial and temporal relationships that we are conscious of ; ie our experience. We are not conscious of them because space and time are "out there" and we are just receiving these; we have imposed those forms, and there is only one possible way to impose them, so only one geometry is possible.

Mathematics formerly was the exemplar of the universal certain knowledge "out there"
Previously, thinkers such as Plato thought of math as universal certain necessary (UCN) knowledge as something out there.
Kant says math IS an example of UCN knowledge, but because we construct it. A synthetic apriori.
For Kant, Euclidian geometry and Newtonian physics can be deduced from the minds system of knowledge.
Kant has answered Hume, at a price; the price is, we do not have knowledge of the world. The world independent of the mind is unknowable. We can know that the world is out there.
Kant and Hume had in common: there is no knowledge of what is out there;
And we can have knowledge as a relationship of our ideas.
And both advocate self activity of mind

But we can conceptualize a different space, in non-Euclidian geometry
(conceptualize or experience?)

Kant's philosophy of how the mind works is very influential later via Hagel in social philosophy.
[This is also similar or consistent with the idea of the holographic universe]

The Critique of Practical reason
The Critique of Judgment

Lecture 8 Science, Society, and the Age of Reason

Reason gives us tremendous power
Technology leads science thru 19th century
Cultural interest in technology lags: we admire science more than technology
How did Newtonian physics effect society?
Broadly applied: if want to make progress, have to do things in "scientific" way
Psychology, sociology, biology,
(can conceive of airplanes etc without science)
"we know more" than anyone in the past : renaissance
Reason allows American revolution to create a better society
Reason is the universal tool to be applied to everything
Enlightenment: we use reason to dispel darkness
The age of reason is a response to science
Did science cause this response
Or did this response cause science?
Longing for secular materialistic society
Religion and philosophy denied
Science can provide liberating power
French revolution: standardize measurement

Rousseau: argued that science and technology make things worse:

Romantics: feeling better than reason; science steamrollering emotion.

Lecture 9 Science Comes of Age in the 19th Century

Most of what science tells us today is beyond our experience;
What's "really" happening or what's real depends on context:
What is happening in human body; what is happening in motion of earth
Sometimes descriptions of "what is happening" conflict with one another
Newton's particle theory of light, Huygen's spherical wave theory of light
Transverse theory; Einstein's Quantum Theory of light
How do we know if any of these is "right"?
Which one works?
It is assumed that if it works, it gives us a correct depiction of reality. BUT
A theory can explain to the satisfaction of a group of thinkers, can make correct predictions, and can even lead to technological advances, but still be wrong. It still may not be true to "reality".

A “successful theory” Is not one that necessarily corresponds to reality.
We can all agree what makes a successful theory, but it may not be proven that it corresponds to “reality”

If successful, why do we want to go further and say it is “true”?.

There would have been no science wars; no internal conflict within science, if scientists did not claim the theory that worked was also a “true” or a correct representation of “reality”. Scientist typically add that statement.

What brought this to a head: debate on what is heat?
Two views: Heat is caloric fluid escaping or particles moving
LaPlace continued to believe in caloric theory for his whole life.

Often a “Crucial” experiment is thought of as decisive; one theory is supported, the other is thrown out.

On logical grounds, the concept of a crucial experiment is thrown out.

Joseph Fourier: wrote an essay on the analytical theory of heat. Judges were Laplace and Lagrange. Fourier made a starting announcement: the mathematical theory of heat is independent of what heat “is” Who cares what it “is”? that is a metaphysical question. Equations allow to predict how heat will behave in a body.

This is like what Leibnitz said to newton.

Fourier’s is a successful theory, who cares what heat “is”

Growing number of theories that describe nature behaviorally

Fourier’s paper was a successful decoupling of the claim that if a theory is successful, then it must describe reality.

Another big development: within 10 years of Fourier’s paper, development of
Non-Euclidian geometry.

Euclidian geometry was the model of the conception of knowledge as universal necessary and certain, keyed to deduction. Euclid’s definitions, postulates, axioms were considered as self evident, and the theorems deduced form the axioms definitions and postulates. Kant argued that it was the only possible geometry. Euclidian geometry considered for 2100 years to be a “True”; a perfect example of universal necessary and certain knowledge, and that spatial relations are correctly described by Euclidian geometry,

Non-Euclidian geometry is the same thing, with one different axiom, and different theorems result.
Parallel line axiom:
Euclid: can only draw one line thru a point that will never intersect a pre-existing line.

Alternatives:
Suppose you can draw 0 lines thru a point that will never intersect a preexisting line

Ie all lines will intersect
(hyperbolic space) on a sphere

So get different theorems that contradict Euclidian, but were arrived at deductively

Riemannian: sum of angles of triangle >180deg
Lobachevskian: < 180 deg
Euclidian = 180 deg

So which one is true of space? Cant tell logically; Only way to know is empirically, but then have lost "universal necessary and certain" character of Truth and Knowledge of Reality .

This means that the connection between the products of deductive reasoning and "reality" is not logical. This reinforces Fourier's move to successfully decouple a successful theory from describing "reality."

This all highlights the important role of assumptions.

Can we trust the concept of "self evident", since things we thought were self evident were not self evident at all?

Non-Euclidian geometry is important: in general relativity where space is curved in dense concentrations of energy or matter, have to use curved geometries; especially Riemannian; in cosmology and string theory need to use hyperbolic geometry.

Assumptions came from Descartes
Newton assumed you could infer from experience axioms that are universal, so can't really come from experience deductively, because experience is particular. Conservation of matter and energy are important assumptions. Below level of assumptions, theories are deductive, but assumptions have not been deduced.
Assumptions bridge the logically unbridgeable gulf between induction and deduction.

Lecture 10: Theories Need Not Explain

Fourier's approach challenges the connection between description and reality

A Causal explanation is deterministic

Effects follows causes

Conservation of mater conservation of energy: fell by wayside;
Followed by conservation of matter energy as absolute principle

In 1930 Niels Bohr responded to a serious challenge to quantum theory based on experiments done in 1920s that suggested that the energy of electrons emitted by beta decay was continuous, not quantized. This would have been devastating to Q theory. To save Q theory, Bohr allowed conservation of energy to be violated in beta decay, so the result was consistent with Q theory. Many scientists agreed with Bohr.

So assumptions can never be relied on to be self evident.

Wolfgang Pauli proposed that instead of violating the principle of conservation of matter, there must be a little particle in the nucleus, eventually called a neutrino, which was not discovered experimentally for decades. This particle is seen to carry away energy so as to restore conservation of energy and quantum theory. This is like feigning assumptions that will rescue the theory. But it also turned out that the instrument that detected neutrinos was built in conjunction with the theory predicting them.

Science and math both challenged:

Roger Penrose argues, as Plato, that math objects exist independently of the human mind. But if they do, how do we know about them? The abstract concept of "circle" comes from the experience of objects.

How is it that we can invent math objects that turn out to describe natural processes so well?
Look at the assumptions.

Three attempts to provide a theory of mathematical knowledge failed to win a consensus, so mathematicians shrugged their shoulders and said, this is a waste of time. Since that time, new brilliant math has been developed without an answer to this question. So maybe it doesn't matter what math objects "are", we just do math. In same way with science, don't ask about "reality", even thou scientists continue to insist the results of their science does represent reality.

This insistence drives science wars.

Important: science exists in history: the historicity of science: it exists in time and does evolve.
Math theories are platonic and timeless within their assumptions. A new recognition in the 19th century:
Essential characteristic of scientific theory: no theory is in the bag because experience is constantly changing.

Dialectic: scientist create new kinds of instruments which result in different experiences, which require different explanations which results in different theories.

Example: historicity of science
Darwin's theory of evolution
requires a reconceptualization of time
We can't predict the future of life form
This is new concept in science:
So time is a dimension in which novelty emerges

Changes that cant be predicted as a matter of principle

Community shares assumptions

Lecture 11 Knowledge as a Product of an Active Mind

Looks like a red apple out there
Senses transform stimuli; are self active
Eyes take in EM radiation, result is color

Use reason to correct the influence of the senses
From time of Plato on, reason was considered to be a timeless neutral faculty;
That reasoning doesn't change what we are reasoning about
What if reason has a transformative effect;
What if reason is self active?
What if reason changes over time?
If so, what happens to our ability to correct the transformative effect of the senses?
What happens to our ability to have knowledge about nature if what it means to reason about nature
Carries with it the same kind of transformations in what we reason about as the senses carry in transforming stimuli. This is what Kant was saying.

Whewell's theory of science:
Science has a deductive structure (proceeds from the general to the particular)
And is therefore universal, necessary, and certain, subject to the assumptions used
In reasoning.

These assumptions are creatively invented by scientists, and Whewell called them "fundamental ideas", wich cannot be deduced from experience; they are derived from experience in a process Whewell called "induction".

He has redefined "induction": normally meaning forming generalizations based on particular instances; it is probable, never certain; now "induction" means insightful idea

John Herschel disagreed; believed scientific knowledge did describe nature as it is, as Bacon described induction, not as Whewell described induction; experience correcting experience; scientific knowledge accumulates; grows.

In France, August Comte founder of sociology; developmental theory of the mind; went further than Whewell in identifying the self activity of the mind as a factor in our reasoning. Said the mind itself develops in time; evolution from animistic fetishistic monotheistically [theological], metaphysical, positivistically (thinking based on facts and their relationships
John Stewart Mill: must know true causes; holds with Bacon original idea of induction.
A system of logic: detailed theory of induction

The point here: self activity of mind, so have to pay attention to history of science

Romantics: feelings count; reasoning not the optimal tool

New philosophies challenge dominance of reason. Kierkegaard, Nietzsche
Reason requires inputs that are not necessarily rational, so reason by itself cannot work
Perspectival interpretation of reason

Idea of unconscious; premises not under control of conscious control

William James: perception of experience has a selective character

What we perceive is based on experience, expectation; mind chooses based on culture etc

Seeing hearing reasoning is not neutral
All this seems to say that scientific knowledge is not objective, objective is not reality, and assumptions needed to construct a deductive theory are beyond our conscious control

Chapter 12 trading reality for experience

Natural philosophers traded in badges for scientist; there was a desire for scientists to distance themselves from philosophy. Scientists do something, as opposed to philosophers. This was ironic, because just as they trade name to scientist, they have to also revert back to philosophy because of the knowledge problem within science that surfaced with a vengeance.

Michael Faraday had physical intuition; spoke of
Lines of force, tubes of force.

Maxwell tried to incorporate this into a math theory
But gave up. [subsequently vector calculus was invented that was able to capture Faraday's concept]

[Math can simulate reality to varying degrees of infidelity]

[Mentions Edison, but leaves out mention of NikolaTesla]

Earnst Mach: The job of science is to summarize experience, not to determine reality, which is a metaphysical question. He especially attacked the idea that the atomic theory meant that atoms were "real" He was ignored in this.

Pierre Duhem: you can never prove the truth of a theory from the results of that theory: the under-determination of theory by facts: the results may be determined by more than just one theory.

The under-determination of theory by facts: is restatement of the fallacy of affirming the consequent

Heinrich Hertz: science always has a certain subjective dimension. There is no logically necessary reason why we pick the assumptions that we use. This is a devastating condemnation of the idea of science as discovering "reality" yet many scientists promote this idea, and the public buys into it.

Historicity: very often scientific theories that were accepted were subsequently shown to be incorrect.

Nothing that we believed in 1900 made it to 2000

John Bernhard Stallo: The Concepts and Theories of Modern Physics: exposed the metaphysical foundations of modern science: scientific reasoning and knowledge is critically dependent on non-scientific assumptions. Which means that scientific claims to be knowledge of reality are non-scientific claims.

All above evidence of underlying ambivalence about what science is knowledge of.
The claim that it works, vs the claim that it works and is true keeps the science wars bubbling.

Lecture 13 Scientific Truth in the Early 20th Century

By early 20th century, science mattered to society because of social benefits. But new theories were arising which threw out the 19th century science. Not improvements of old theories, but new realities

Henri Poincare: Poincare conjecture: topology of multidimensional space
Russian Gregori Perelman offered a proof; seems definitive

Poincare: founder of chaos theory
Only objective reality was what he called the internal harmony of the world
Math was a convenient language for articulating this harmony.
It captures the harmony of the world.
What makes scientific knowledge objective is that it is a shared
Conceptualization of experience.
For Poincare, "reality" does not exist independent of experience
Science is truth and knowledge, but not in the absolute sense of philosophers

Percy William Bridgeman
Measuring operations are able to cause us to re-conceptualize reality and what we mean by reality.
He developed a philosophy of science that he called operationalism: the meaning of a scientific concept is the set of operations that must be performed in order to measure that concept.
Again the object of science is not "external reality"; it is the resultant of a network of concepts
Science is about objects that scientists themselves create thru the concepts that they use.

Bertrand Russell
One of founders of "analytical philosophy"
Conviction that the key to knowledge is logic; science is knowledge of external world;
Scientific knowledge has a deductive logically necessary universal character;
The world is a collection of facts. Importance of language in capturing facts about the world
Wanted to write a scientific description of the real world
Led to development of logical positivism.
Tried to reduce math to logic

Lecture 14: Two New Theories of Scientific Knowledge

Beginning of 20th century: scientific imperialism: science uniquely the route to knowledge and truth of reality; the only rational world view. Lenin and Stalin criticized the Earnst Mach principle that the object of scientific study was NOT the defining of "reality" to protect Marx's philosophy of history and science (scientific materialism). Stalin proclaimed that relativity and QM were not true because they were probabilistic contradicted Marx's philosophy. Russian scientists who wrote on these subjects under Stalin's rule had to preface their books that relativity and QM were useful but not true.

Lesson: science usually assumed to be "true" knowledge.

Dilemma:

But over and over we find that theories we thought were true turn out to be wrong, even though they provide predictability and useful results.

But if as Mach and others believed, that theories are merely summations of experience, how can they lead to descriptions of novel phenomena that no one anticipated?

How come mathematics , which we invent, is so effective in describing “reality”? (Wigner: unreasonable effectiveness of math in natural sciences)

Pragmatism: Charles Sanders Peirce
Rejected Kant’s views
Belief has to be able to be “cashed in” : keyed to action
When action beliefs become routine, are called habits.
William James promoted pragmatism
John Dewey developed the philosophy of pragmatism; based on experience
Saw science as way to predict and control
Scientific knowledge is particular, conditional

Logical positivism: (Betrand Russell) scientific knowledge is universal necessary certain:
Scientific knowledge has 3 components:
1: observational sentences (observed facts about the world)
2: theory sentences, which are abstractions
3: a set of rules for connecting the two.
It was discovered that it could not work; can’t separate 1 and 2
Still remained dominant into 20th century (1960s)

Lecture 15: Einstein and Bohr Redefine Reality

Even founders of logical positivism recognized it couldn’t work, but it dominated till 1960s. Why?
Who as paying attention? Perhaps not scientists, but philosophers.
John Dewey wrote *The Quest for Certainty* (1929) in which he argued that the quest for Plato’s God’s definition of knowledge is religion under another name; its not good philosophy. The Humanist Erasamus said the quest for certainty is the comedy of the higher lunacy; a form of madness. Still many brilliant minds pursue this. Come back to question of why.

The justification for persistence in believing that theories disclose reality is founded in 20th century physics: radioactivity, x-rays; redefining reality. Seems to be revealing realities. Size of universe; galaxies, etc. there are hundreds of millions of stars; these are not claims of experience, they are claims of reality. The way things are. Controversy: Mach school says OK to consider atoms as a working concept; can get useful results from this, but don’t believe really are atoms. Boltzmann & others disagreed. There ARE atoms. In 1896 radioactivity was discovered; x-rays were discovered; the internal structure of the atom was discovered (by JJ Thompson, who argued the atom is not simple; it is made of electrons) Millikan measured charge and estimated mass of electron. When can measure weigh and calculate, looks like “atom” is not just a conceptual tool; it looks like reality. Relativity and Quantum theory seem to open up whole new realities.

Lessons not learned: science is historical; scientific truth and knowledge emerge in time; that the assumptions that are required to define scientific objects and theories change over time; so that scientific knowledge should be perceived as an open ended process, and at any given time has a conjectural character. (assumptions can change); theories correctable.

Special & General Theory of Relativity:
Consequence of Special Theory: matter and energy intro-convertible; this redefines Newton.
GT of R: redefine relationships between space time matter and energy; space and time have properties dependent on what is happening In time, and what is in space. So that depending on the concentration of matter and energy, space will have a certain shape. In the overall universe, space is uniform or flat, conforming to Euclidian geometry, but in places where there is lots of matter, space is curved, so non-Euclidian geometry must be used. Also where there are concentrations of matter and energy the measurement of time changes.

These are not just improvements; they displace the old reality. Did the electron exist before J.J. Thompson "discovered" it? Well yes… but this does not attend to the distinction between a scientific object and an object. A scientific object only exists when it is defined, and when redefined, cease to exist. Daltons atom, as a scientific object, ceased to exist when Thompson redefined the atom to have an internal structure. Thompson's atom ceased to exist as a scientific object when Rutherford claimed the atom was mostly empty space, with a positive charged nucleus and electrons orbiting around it. Rutherford's atom ceased to exist a few years later when Niels Bohr gave his quantum theory of the atom. The Bohr atom ceased to exist when the neutron was discovered; giving the nucleus an internal structure.

We have not annihilated the atom by replacing it with a new definition.

It was already recognized in the 1930s that if we make an observation of an elementary particle at Fermilab, using special highly technical equipment [made for seeing particles], and we are making a scientific observation that will go towards making a scientific explanation, that explanation is infected by the theory we are using to generate the observation. [put anther way: we have a theory that matter is particles, so we construct a machine that can see particles, which goes a long way towards confirming our theory that we will see particles]

Quantum theory:
Based on Planck's tentative suggestion that EM energy seemed to be only absorbable or emit-able in packets, not continuously as Maxwell's theory required, Einstein took this as a fundamental fact about reality in his 1905 quantum theory of light (The Photoelectric Effect Paper): light behaves as if it were a dilute gas, made up of immaterial particles that have a characteristic frequency, associated with Planck's constant.

In his paper Einstein states there is a profound difference between physical models based on the wave vs particle concept. Nothing can be both a wave and a particle. Therefore, Planck's equation, which is made up of wave and particle aspects, although it gives correct values, cannot be used as a picture of reality. Einstein redefined wave theory to provide new quantum theory of light ("what's really out there")

But Einstein's light quanta (photons) have a dualistic character; they are particles, however are associated with a frequency. This led to what for a long time was called wave-particle duality. Bohr argued that this duality is conceptual; that it reflects a fundamental feature of human thinking, a limit of our conceptual ability. Bohr, Heisenberg, Pauli,etc argued against Einstein, de Broglio and Viennese physicist Schroedinger, insisting that the object of scientific knowledge is not reality, but experience.

Bohr's quantum theory: of atom 1912-13. He announced a set of rules for how electrons behave when they are circling the nucleus. These rules seem quite arbitrary, but "work; i.e. make valuable experimental predictions"; they violently contradict the requirements of Maxwell's laws.

Heisenberg's matrix mechanics are a purely empirical correlation of the frequencies of light emitted by electrons as they change their orbits around nuclei and contrasts with Schroedinger's more classical deterministic model of same phenomenon. They were later shown (by Paul Dirac) to be translatable, even though they are philosophically incompatible. What pops up here is Fourier: a set of equations can work, without our understanding what they mean physically. This led to a dispute between Einstein and Bohr; is QM a complete theory? Bohr claimed it was, despite of the fact that it was a statistical theory and has no physical interpretation. Einstein claimed it was not complete because it was not deterministic and causal.

Lecture 16 Truth, Ideology, and Thought Collectives

A western notion: that Reason and knowledge and thinking are the activity of an individual. This notion of intellectual individualism was challenged:

Naturalistic theories of mind: we do not control our minds; we do not control the content of our consciousness. See this in Hobbs, but more so in Hume in his associationistic theory of psychology, which says the flow of ideas in our minds is determined by certain laws of association: continuity, causality

The content of consciousness is determined by unconscious factors. (Freud and Jung)

Reasoning is a social activity: historicist view: Gottfried Herder, who built on the ideas of Italian Giambattista Vico:
Every culture has a distinctive character.
Ideas can only be understood in the context of their time and total cultural context.
This is echoed by Nietzsche's belief that reasoning is perspectival; always from a certain perspective; ie within certain set of assumptions. Gestalt psychology; selective attention; building on an idea.

Carl Marx argued that consciousness is determined by social factors, which are themselves determined by economic relations and those are influenced by the state of technology of a society.
Thinking is influenced by material factors and social relationships; for him, in a society where there are different classes and there is a class conflict, thinking is ideological;. The way you see the world depends on the class you are in. There can be no free or clear thinking unless there is a classless society.

This idea appears in the work of anthropologist Franz Boas 1858-1942; the effect that languages have on the way we experience the world, sometimes called the Sapir-Whorf hypothesis.

This line of thought comes to a head in 1930s in the work of 2 figures:
1)Carl Manheim: German sociologist who published *Ideology and Utopia*, the founding text of sociology of knowledge: knowledge is a social construct; has a social dimension to it. He argued that knowledge is ideological in the sense that all claims to knowledge reflect a bias or set of influences; that claims to knowledge are not neutral; they always incorporate values that reflect the biases of the individuals or groups that claim that knowledge.

Manheim excluded science and math, because he was also influenced by scientific imperialism. He subjected the conduct of science to this claim but not the content. DJ Bernal, physics and chemistry; was a politically active Marxist, and argued that the content of scientific theories also reflects the prevailing values; these ideas were dismissed; assumed to be due to his Marxist leanings.

2)Ludwig Fleck: Polish world class immunologist; wrote *The Genesis and Development of a Scientific Fact (*1935*)*
Addressed the knowledge problem in science. He took the history of syphilis, and the history of the test for it, as a vehicle for exploring the way that scientific knowledge is socially produced. That reasoning is a social phenomena, not an individual one: individual scientists do not think; Scientific collectives think through individual scientists. Of course thinking goes on inside the minds of individuals, but what Fleck was arguing was that that thinking was shaped and controlled to a degree by the collective to which that individual belongs. And if an individual does not belong to the collective, they cannot be doing science.
Just as language is a fundamentally social phenomena, science is a fundamentally social phenomena. What it means to do science is to employ assumptions, terms and definitions; to reason in ways that other scientists will recognize and respond to.
Fleck made three observations:

He showed how through time, from 16th century to 20th century, the conception of syphilis as a disease changed in ways that reflected prevailing social ideas and values. The content of science was NOT free of influence, because the influence from society could effect the assumptions that were made,
Which could effect the reasoning the scientists used.

Fleck showed that scientists have a clear prejudice to reify-to make things out of processes and patterns. Syphilis is now a "thing"
Classification is fundamental to doing science, and classification schemes are not unique.

To do science at all, you must begin with active associations, or assumptions or measures (must be measurable). You must first impose a metric on experience before you can reason about it.

Example: cant know the volume of a room until a measure/metric is given.

Once you identify the active associations (assumptions) then what he called the passive relations come out deductively. Ie your assumptions determine the results.

So, scientific knowledge is objective (same answer; same assumptions) and real: it gives a definite result; but is not unique; will get different answers depending on different assumptions

But there is no objective way to determine assumptions. Only a collective can say what assumptions are appropriate
For Fleck, thought collectives practice science in accordance with certain thought styles: certain sets of assumptions and principles. Evolutionary biology, quantum theory: thought styles.
He anticipates Kuhn's Image of science

Lecture 17: Kuhn's Revolutionary Image of Science

In the 1960s, science and technology became issues for the public at large, broader intellectual consideration, and for other disciplines.

Political critique anti war, environmental, anti corporation;
Science and technology became Targets because they were considered co-opted by the military industrial complex. A pivotal factor in intellectual reassessment of science was physicist turned historian of physics Thomas Kuhn, author of *The Structure of Scientific Revolutions*.

No single feature of Kuhn's book is new. Starting in the 1800s, there was long tradition of eminent thinkers who asserted the historicity of knowledge, including scientific knowledge. That scientific knowledge represents interpretations of experience rather than revealing an underlying independent reality.

Response to Kuhn was phenomenal; everyone was reading his book, like it was news, even though it was not new.

Kuhn argued that the history of science properly applied shows that claims of the objectivity of scientific knowledge are not supportable.

People had been doing history of science for a long time.

"properly applied" means that until now, historians of science have been "groupies" of the science community; they have accepted the notion that science is approaching a "correct" view of reality, telling a chronological story and focusing on the present as superior to the past. It is the story of the progressive ascent of the mountain of truth. Individual scientists see, and take us along the "right" path up the mountain. Also called a Whiggish interpretation: a revisionist look at the history of science which makes it seem as though the present is the inevitable outcome of the past. Kuhn says that the historians of science have not been asking the right questions. They have not been looking at the process of discovery. Lets look at the reasoning and the context of the process of discovery. When you ask those questions, you discover that the formulation of scientific theories is much more complex, and much less clearly the application of logic to data.

Kuhn's discussion of Lavoiser's "discovery" of oxygen: combustion is the entering of oxygen.
He was in rivalry with Priestley, who said combustion was the expulsion of phlogiston. Numerous famous scientists agreed with Priestley. In the context of discovery, defending theories we today assume to be wrong does NOT appear to be irrational. These scientists defending phlogiston. could give reasons why Lavoiser was wrong. The same facts were available to Lavoisier's group and Priestley's group, but they reached different conclusions. In each case they were using logic, but they were using different assumptions.

Two predecessors of Kuhn: Hungarian physical chemist Michael Polanyi (1891-1976) became philosopher of science because he was concerned with the nature of scientific knowledge and the public image of the nature of scientific knowledge in determining public policy. His position was that scientific knowledge had been misrepresented to the public as merely logic applied to facts. He said science was an Art, meaning a craft like skill. Judgments need to be made in doing science that are not logical, but require intuition. (this is what Poincare believed in the doing of math) The scientist is engaged as a person, with moral and spiritual values.

American historian of physics Norwood Russell Hanson (1925-1967) published *Patterns of Discovery* was influenced by Wittgenstein. Eyes don't see; people see, based on our personal experience, values, etc.

Cognitive neuroscience has evidence that perception is shaped by language, cultural background and expectations. This argues against logical positivist philosophy; ie is opposed to idea that theory and observation could be segregated. Observation is always theory-laden.

Kuhn's model for science cannot be dismissed, his critique of science survives even if it is wrong in detail. When a new field emerges, scientists come to an agreement on a certain baseline of definitions. Kuhn calls this a paradigm: a conceptual framework that everyone agrees with. They are playing the game of Newtonian physics; of molecular biology, etc. The paradigm defines research programs. Kuhn calls this normal science; most are exploring the paradigm, not trying to make breakthrough discoveries. Because paradigms are interpretations (models), and are non unique, inevitably new experiences using perhaps new ways of seeing will lead to an accumulation of anomalies.

If the anomalies cannot be addressed by the theory, if the community agrees that the theory cannot handle the anomalies, you have a crisis. The crisis may be resolved by a replacement of the old theory or paradigm with a new paradigm which does explain the anomaly.

New paradigms define new realities, and paradigms are incommeasurable. The concept of paradigm is fuzzy, the concept of incommeasurable is overstated etc. but his basic model can't be dismissed

[lecture does not seem to follow up on or address the Lavoisier-Priestly disagreement. Lavoisier's results seem in fact to have led to further discoveries. What discoveries can be made by using Priestley's assumption of phlogiston?]

Lecture 18 Challenging Mainstream Science from within.

Where do the assumptions/metrics come from? Has been argued that we find them; that the metrics arise from nature; that the metrics emerge out of our experimental interaction with nature. Then we would have to ask why the metrics change? This suggests the metrics or measures we use to make experience intelligible are assumed. They come from us. That does not mean it is arbitrary or whimsical. They are related to nature but not unique. See this in string theory: they are looking for assumptions that will allow them to deduce the phenomena that string theory should explain, in particular a quantum theory of gravity. Often starting out, scientists will say, let's assume this; no, lets assume that to explain something. Does that make it true??? That's the question.

Plato and Aristotle tried to refute Protagoras, who said "man is the measure of all things." What did he mean? We can't be sure, but we can probably agree that he was right about the following: Man is the measurer of all things: That we impose metrics on experience in order to make it intelligible. This is the sophist position. To the extent that experience is intelligible; to the extent that truth, reality, knowledge have meaning, those meanings derive from us, not from nature. This implies there is no natural metric for experience. This relates to the taxonomy or classification problem, which is most famous in biology. Classification schemes are not facts; they are related to facts. The naturalist was challenged to identify thousands of biological species. Is there a natural way to classify?
16th – 18th century biologists struggled with the question. Linnaeus was a pivotal figure; he classified plants based on sexuality. What could be more natural? Reproductive parts of plants are the basis of class order genus species, which triumphed over the world. He thought he was correct until towards the end of his life additional specimens were discovered which proved he was wrong. It was found that despite similar reproductive systems, some plants had otherwise very different structures. So his scheme was then considered artificial rather than natural, but the fact that there are "species" in nature

implies that there IS a natural classification scheme. Plato argued there is only one correct way to divide up nature. In the 19th and 20th century the argument became how do you define species. Biologists are still arguing over the definition of "species". Classification is an issue in science in general and in particle physics in particular. In the 1960s, particle accelerators had created in their collisions 200 "elementary particles", which is ridiculous. How do you classify them? Murray Gell-Mann and Yuval Ne'eman: organized particles into 8 families (the 8 fold way). This was replaced by quantum chromo-dymanics: all particles covered by assuming there were six quarks and anti-quarks. Is the 8 fold way artificial or natural? Are quarks artificial or natural, or are they both just a way to classify? Take the example of organizing books. There is no "natural" or right way to do it.

Hillary Putnam and Nelson Goodman argue that scientific concepts are classification schemes. Defining space time, etc are metrics; measures that then allow us to begin reasoning. If all classification schemes are artificial, we need to think differently about scientific knowledge than if they are natural. If there is a natural classification scheme, our job is to find it and just use that.

An underlying issue in the conflict between logical positivism and pragmatism:
Is our humanness relevant to what we mean by intelligibility of experience?
To what we mean by knowledge truth and reality?

Analytical philosophy argues that our humanness is irrelevant because the truth is "out there"
It is what it is independent of us. The Continental philosophical and pragmatist view (fuzzy thinkers according to the Analytical philosophers) is that our humanness is inescapable; that knowledge truth and reality can only have meanings relative to how we choose to define them based on our interest in experience; on our expectations and what we want to do. And we accept a theory as true if it fulfills those expectations. And if it stops filling our expectations we move on, declaring new knowledge truth and reality.

Claude Bernard, (1813-1878) experimental biologist; follower of Comte; said concepts are like scalpels; use them until you are done, then throw them way and get another one. That is a positivistic view of concepts; they are an artificial classification; as opposed to the concept of "cause" as a sacred. It has one correct meaning. There is only one correct definition of space. (natural classification scheme)

Another issue raised my Kuhn's book about rationality of people who defended views that are considered "mistaken".

Three highly credentialed outsiders in their own professional fields
Halton Arp should be considered a leader in astronomy, but is an outsider from a Kuhnian paradigm perspective because he challenges the prevailing paradigm of the expanding universe; of how we should interpret the red shift in light from distant galaxies. He argues that there is observational evidence showing that quasars, objects with very high red shifts, are much closer to us than their red shift implies, that there is something else out there causing the red shift. He has argued this for decades and has collected what appears to be a convincing body of data to prove his point. He presents anomalies that are not enough to force a crisis, given the stakes of cosmologists in the prevailing paradigm.

Thomas Gold 1920-2004: Cornell physicist. Had a number of theories that turned out to be very fertile, but some that were mocked until it was shown that there was something to them after all.
Published a paper on how the inner ear works; was dismissed for decades till he was proved correct

For years he argued that methane-natural gas- and oil are produced abiotically through geological processes deep within the earth, and deep biological processes. Bacterial communities deep within earth also produce. Not all the residue of fossilized carbon material. For decades these were considered wild ideas, but now are considered credible. He was marginalized as a maverick physicist.

Milford Wolpoff; b 1942; anthropologist specializing in human evolution. Prevailing paradigm is migration out of east Africa. Wolpoff argues that homo sapiens evolved multi regionally.

Kuhn argued that it is in the nature of theories to evolve over time. Ie, it is natural that anomalies will arise over time.

Some theories evolve so much that there is a change in name; as Newtonian vs Relativistic, but many theories evolve without a name change. Astronomy has changed greatly since the time of Copernicus, but we still call astronomy today “Copernican.” Planets don’t move in ellipses; ellipses are closed curves, but because the planets are moving around the sun, and the entire solar system is moving, the planets never return to the same absolute position. This is an example of Fleck’s concept of “reification”: making facts out of assumptions.

Same with “big bang theory”: it is unrecognizable when add in inflationary theory, dark matter etc.

Disk 4

Lecture 19 Objectivity Under Attack

Israel Scheffler (b 1923), in book *Science and Subjectivity*, based on 1965 Oberlin Lectures, argued that Kuhn’s book was dangerous because it threatened to undermine fundamental intellectual and moral values. He claims it opens the door to the relativization of truth, and would result in tribalization of science into ideological camps. This is exactly what Plato would have said about Protagoras’ view. Scheffler’s view of science: reasonable men who use facts and data to arrive at conclusions which compel without coercion.

At the other end of spectrum in criticism of Kuhn’s book: Paul Feyerabend 1924-1994, who said Kuhn did not go far enough, and should have said the concept of truth is relative (which Kuhn did not say) Feyerabend disagreed with Karl Popper who advocated that statements of scientific theory must be falsifiable in principle.

Feyerabend said that rationality is not the “last word” in truth and knowledge. Rationality is not the only means by which we anchor claims of truth and knowledge. He believes in a historisist view of truth and knowledge. That what we mean by truth and knowledge are not facts about the world, but are conceptual categories that we impose as part of the effort to make experience intelligible. That means if scientific knowledge is historical, it is relative. For him relativism does NOT mean anything goes. His relativism: the analysis of truth and knowledge claims are relative to the context in which they are made. Published book *Against Method* in 1975. It’s not that science is irrational, there is just no one formal method that is guaranteed to take you from data to a correct theory of the data. Ambiguity and contradiction cannot be entirely eliminated from our reasoning about experience. This is not so unreasonable. Fuzzy logic sometimes allows for better results. There is a branch of math today called paraconsistent logic where contradictions are allowed; where you can reason effectively about complicated situations in which there are logical inconsistencies. Human beings are loaded with logical inconsistencies. Feyerabend was more reasonable than he has been portrayed

Another of Plato's enemies was Gorgias, who argued that reason was intrinsically flawed, logically. We have to deal with ambiguity and contradiction.

Scheffler's worst fears were realized in French sociological philosophers Michel Foucault (1926-1984) and Jacques Derrida (1930-2004). Independent of Kuhn's critique, and the anti-establishment critique of science and technology in the US, these two launched major critiques that were highly influential, primarily in Europe, on the concepts of objectivity and knowledge. Foucault did series of studies on sociological terms such as madness, illness, sexuality, crime, showing how, in each case, what we meant by these terms; how they were defined, was, to use a later expression, socially constructed; was relative to changing social context. He extended his study to the term "knowledge", and believed it was keyed to specific social contexts. This is another way of showing what Feyerabend meant by relative, but using case studies. Our classification schemes are artificial. Derrida, initially a friendly colleague of Foucault, later disagreed with him and launched an even more fundamental critique of the Western rationalist tradition, built on a theory of language of the Swiss linguist Ferdinand de Saussure, who argued that language is a closed system of arbitrary signs that has no connection to what language refers to. Though this sounds strange, de Saussure had a point. The meaning of any sign in a language is derived from its context within the language. Derrida developed the concept that there is no such thing as "the meaning" of any text. One cannot say the meaning of any text is bounded in any particular way. He then generalizes the meaning of "text": a corvette is a text; an SUV is a text, etc; each is a system of signs with all kinds of meaning associated with it. Cant say what the "right" meaning is. He defined "deconstruction" as a way of exposing those levels of interpretation that are normally hidden from us by authorities (perhaps the writer of the text), who want us to have a particular interpretation. Foucault and Derrida were champions of hermeneutics: interpretation, as opposed to analysis in uncovering multiple layers of meaning. Science at any time gives a particular interpretation of experience, but there is no limit to the interpretations.

Lecture 20: Scientific Knowledge as Social Construct

Social construct was the buzzword of 1970s-1980s; now not much used. Jerome Ravetz was a socialist political activist, who was expelled from the US for a number of years. He wrote *Scientific Knowledge and its Social Problems* (1971) "doing science is a craft" an echo of Polanyi. Like any craftsman, scientists are responsive to the social context in which they do their work. To say that science is a craft is to say that it occupies a social niche, that it is valuational. Ravetz said this about both scientific and technological knowledge. Classically science is looked at as value neutral: you can use it to make bombs, or make medicine.

Scientists define problems that they decide to work on. The scientific community decides which solutions to the problem they like.

It took 6 years before Howard Temin's (1934-1994) claim that RNA could reproduce itself by connecting to DNA (reverse transcriptase) was accepted.

For years Stanley Prusiner was mocked for his concept of prions, but then mad cow disease came along and he won the Nobel prize in 1997.

Technology impacts society negatively as well as positively.

In the 1970s-80s, new study programs developed on Science, Technology and Society which spread across universities in the US, Europe, and East Asia. These programs are a "symptom" of social construction theory, of the perception by the public that science and technology are "issues" for society; not just a cornucopia of blessings.

These study programs were also a cause of social construction theory because they gathered scholars from other disciplines who were looking at science and technology as factors driving social change. Whole professional community grew oriented on studying the history of science, including psychologists, sociologists, philosophers, economists, and some scientists. Before this, the history of science had never been popular.

Out of this community a group of sociologists arose that were willing to apply to science the same methods that sociologists or anthropologists used to study a remote culture. Let's look at what scientists do and see how they come up with their theories.
Laboratory Life (1979) by Steve Woogar and Bruno La Tour, published after several years of experience living at the Salk Institute for Medical Research. This book summarizes their experiences in a world class lab. They show that doing science is a process that is not just about reasoning about data. La Tour later proposed "actor network theory" to capture how communication among scientists is involved. The idea is to create a network of allies that already accept what you are doing so that when you make your announcement, the allies are ready to support you. They argued that in some way the scientific community "makes" scientific knowledge.

The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Knowledge (1981) by Karen Knorr-Cetina. Pushes further the idea that it is the claim to knowledge that Is determined by the scientific community. Validation of claim to knowledge is made by the scientific community.

The book *Science in Action* (1987) by Bruno La Tour, Goldman believes, epitomizes the social construction theory of scientific knowledge of the 1980s. it said that nature plays almost no role at all in validating scientific knowledge. This outraged scientists. La Tour was noting that the validation process is a social process. A number of books were written in the 80's with this same message. We see a certain glee in the non-scientific community in taking the hard sciences down a notch, which helped to make their case overstated.

2 books bracket La Tour's book:

Harry Collins *Changing Order* (1985)
A "strong program" in the Sociology of Science: applies sociological methods to science the way you would apply it to any problem, without making any judgment about what makes good or bad science.
3 case studies:
1: How Complex the process is of replicating a newly invented instrument: a laser; how do you get it to work in a reliable way? Good example of how theory effects the construction of instruments, so that the observations you make already incorporate the theory and the assumptions on which that theory is based. (also see this in Pickering book)

2: Joseph Weber (1919-2000) claimed he had detected gravity waves via an instrument he built, which are predicted by the General Theory of Relativity. His results were not repeatable.
In a follow up book, Collins looks at Weber's career, notes NSF/NASA spent 350 million dollars on Laser Interferometer Gravitational-Wave Observatory (LIGO) in the SW US, but have yet to find evidence for gravity waves.

3: The scientific communities dismissal of ESP research as pseudoscience, despite the fact that this research appears to follow the scientific method, and make claims that are documentable.

Andrew Pickering *Constructing Quarks* (1984) Pickering is a very knowledgeable PhD in physics, who followed the history of elementary particle physics since World War II. He argues that the experimental data supporting the notion of "quarks" is intrinsically equivocal; theory dominates the data. When you look at the outcome of an experiment with a particle accelerator to get data on which to build your theory of elementary particles, you are already using a theory that tells you what the data means, so there is a kind of circularity associated with the experiment. When researchers at Fermilab particle accelerator at Batavia Illinois finally identified the top quarks after 12 years, they looked at millions of interactions and announced "these are the top 6 quarks". How do you know that? How do you know what's signal and what's noise? You have to use the theory you are trying to confirm to make sense of the data. To do this you need to make non logical judgments. In a complex instrument, how do you know the results are due to nature rather than the instrument itself. Hobbs asked same question about the air pump.

Lecture 21 New Definitions of Objectivity

On behalf of the scientist claim for objectivity:
Scientists talk realistically about their work, as if it discloses nature "out there"; this is true even of scientists like Earnst Mach, with his phenominalism as a way of understanding scientific knowledge

Objectivism: the classical view of science – that the object of science is nature, not just experience. This is deeply woven into the fabric of science. So the critique of this objectivist or realist view of scientific knowledge must be understood as a critique of the concept of knowledge. No one denies that the science "works", that the theories accurately predict results. No one is saying the theories are socially constructed so the electronics does not work. What shall we understand by the word "knowledge"?

In the end, the social construction claim has a vacuous quality. Telling us that scientific knowledge is socially constructed does not tell us anything about the "validity" of that knowledge. The claim that science is socially constructed, that the validation of scientific knowledge claims is critically dependent on the scientific community's definitions of the concepts that it employs, the principles that it adopts, and the assumptions on the basis of which it reasons, does not tell us that the outcome is not valid
[it may be real, or it may not be]

What does it tell us?

3 programmatic approaches:

Carl Hempel 1905-1997. Was a logical positivist that rescued out of the failure of logical positivism what he called a “covering law” model; a deductive-nomological model: scientific explanation is deductive in character, and it is based on universal laws of nature from which specific phenomena are deduced. There is a critical difference between this and logical positivism. This is about scientific explanation, not what science is about. It is a model of how scientific theories explain. A shift in emphasis from explaining scientific knowledge to explaining scientific explanation. Influential in 1950s-60s.

Post Kuhn:

Willard van Ormin Quine 1908-2000: naturalized epistemology: Essay: *Two Dogmas of Empiricism* (1950) Was taken as a smoking gun for the failure of logical positivism. It started the “naturalized epistemology” movement:

Epistemology (the study of how we know) itself should be the subject of a science, not philosophy. The “theory of knowledge” should not be a branch of philosophy, but a branch of science. (more specifically, cognitive neuroscience)
Ie. How information is entered into nervous system and comes out as theories etc.
A new way to anchor that scientific knowledge is objective and is about the world.
It is objective because it is anchored in (neuro)physiology; and it is about the world because it is our response to the external stimuli.

Donald Campbell (1916-1996) “evolutionary epistemology” He was a social psychologist who became very concerned about the social constructionist movement for similar reasons as Schefler. He called the social constructionist advocates “ontological nihilists”, and believed if you undermine the concept of the objectivity of scientific knowledge, then you are on the slippery slope to anarchy. Evolutionary epistemology: our nervous system evolved: it is clearly adapted to the external world. For Campbell, science is permanently conjectural and corrigible.

Most philosophers of science are objectivist; they do NOT accept the social constructionist claims; they are anti-relativists; yet they know that Kuhn and the social constructionists have a point. They have to work hard to support a “neo-objective” approach to science as knowledge.

Hilary Putnam (b 1926) Harvard philosopher wrote *Realism With a Human Face* (1990) developed a view of science as “internal realism”; similar to Poincare’s notion that objective reality is the internal harmony of the world.

Internal realism: we need to conceptualize to reason; concepts are classification schemes, and they are neither natural nor unique. Within a scheme of classification, scientific knowledge is always tested against its implications for experience.

Scientific knowledge is not absolute, nor is it progressing towards an absolute, but it is objective in the same sense of a map being objective: what do you want to get from this map?

The position of internal realism does not give up connectedness with the world; it retains objectivity, but without the ontological claim, that the object of scientific knowledge is an independently existing reality.

24:35

Nelson Goodman: *Ways of World Making* (1978) his version of this is that the only way we can respond to experience in science is some sort of description, and there is no such thing as a unique way to describe an experience. So the history of science is the history of re-description. We will always be bounded by a description. Newtonian, Einsteinian, QM descriptions; this has parallels in the arts: realistic, impressionistic, fauve, abstract expressionism, cubism, non-objective. Impressionism is not superior to neoclassicism, it is just a different description, based on different assumptions. Goodman argues in book *World Making* that science is one description of the world; and not the uniquely correct way of making the world.

Phillip Kitcher (b 1947) defends the mapping metaphor: Science can be an interpretation of experience and can be objective, in the same way a map is.

Ronald Giere argues scientific theories are models, or computer simulations of experience.

Physicist Robert Fine: "the natural ontological attitude" *The Shaky Game: Einstein, Realism and The Quantum Theory.* 1986 "common sense realism"

Bas van Fraassen philosopher of science argues that scientific theories should be accepted as empirically adequate (constructive empiricism))

Scientific theories have a primarily empirical character, and there realism ends at that empirical level.

Imre Lakatos (1922-1974) Hungarian refugee

Lecture 22: Science Wars of the 21st century.

Name "science wars" erupted explicitly in 1996

In the 1960s, the scientific community ignored the criticisms; but by the mid 1980s, things had become serious enough so that there was enough support in the "academy [of Science]" for the ideas of Foucault, and Derrida and generally for the French intellectual establishment, that some members of the science community began to take it seriously enough that they needed to respond to it. So we see a counter attack on the part of the science community.

There was a long and thoughtful response to Pickering's book *Constructing Quarks* by Silvan Schweber, a highly successful physicist turned historian, especially of QM. His review was co-authored by Yves Gingras, sociologist and historian of science from the University of Quebec, in 1986. The review was published in *Social Studies of Science*, a journal whose readers would be expected to be sympathetic to anti-science sentiment. They argue in this review that while Pickering's book is a technically competent history of elementary particle physics since World War II, Pickering's interpretation is flawed because methodologically Pickering has done something inappropriate: he has used his antecedent commitment to the social constructionist view of scientific knowledge, to cherry pick those events in the history of elementary particle physics that supports his interpretation.
Specifically:

1 primacy of theory to observation and data.

2 the necessity of contingent judgments that need to be added to logic and data in order to have a theory.

3 the role that the scientific community plays in validating those judgments, so that the interpretation becomes theory.

However, what Pickering was doing was exactly what the social constructionists said scientists do: he was doing what scientists do, which was interpreting events of what was happening in the particle physicist's laboratory that made sense within the framework of social constructionist theory, just as scientists give interpretations of data and observations within the framework of the assumptions they have made. Pickering's method was the method of the science he was applying his method to. Schweber and Gingras did not seem to have recognized that.

There was also a reaction by the non-scientific community towards the anti-rationalism of Focoult and the French intellectuals, post modernism and deconstructionism.

Three books reflect this:

Allan Bloom 1930-1992 *The Closing of the American Mind* (1987 best seller) Bloom was a flamboyant political philosopher at the University of Chicago. He argued that anti-rationalism was undermining all cultural values.

E.D. Hirsch educator, *Cultural Literacy: What Every American Needs to know* (1987 best seller) Followed up with Core Knowledge series (www.coreknowledge.org)

Alain Renaut, a Frenchman, along with other French intellectuals who opposed the negative political and social implications of Focault and Derrida, and in particular the claim of Derrida that the self is socially constructed. The implication is that society is superior to the individual. Renaut and colleagues were concerned that this opens the way for anti- human rights, anti personal rights, and oppressive governments.

Renaut argues in *The Era of the Individual*, that two types of individualism need to be distinguished: Radical individualism (social atomism) which is selfish, based on the notion of forming relationships based of their usefulness, as in entering into social contracts; the other type of individualism is not selfish: the autonomy of the individual in a social context to choose to relate socially.

The most powerful counter attack against post-modernism and its subset social constructionism was by two scientists; Paul Gross and Norman Levitt in book *Higher Superstition* (1994) it was a polemic; a "flame", frontally attacking left wing academics and their support of a movement which the authors saw as undermining social faith in reason and science, which the authors saw as very damaging to society as represented by feminist and black science, radical environmentalism and social construction notions of science. They argued these groups didn't know any science, often misrepresented science, and their own arguments that everything was ideological were self defeating, because if that's the case, then so is what their saying. Many in the science community cheered Gross & Levitt on. In the following year the NY Academy of Science held a conference, published as *The Flight From Science and Reason* (1997)

In 1996, physicist Alan Sokal submitted article to journal *Social Text*, the flagship journal of the social constructionist/ post modernist movement. The title of that issue was Science Wars. His article was

Titled *Transgressing the Boundaries: Towards a Transformative Hermenutics of Quantum Gravity* Sokal argued that the leading edge scientific theory of Quantum Gravity (outgrowth of string theory), is socially constructed. Sokal was writing a parody of the kinds of articles he wanted to critique. He studied these types of articles and constructed this article that from a scientific perspective is nonsense, and took a gamble that the editors would be so tickled to have a working scientist join them that they would not send it out for review, and they did NOT send it out for review, and published it. Sokal also arranged With the editor of Lingua Franca, a humanities magazine, to print the expose of his hoax. (Google sokal hoax)

This resulted in cheers from the scientific community, but cries of "cheater" from the humanities community. Steven Weinberg was one of the strongest defenders of Sokal. He thought this would put the last nail in the coffin of post-modernism and social construction theorists. On the other hand, Israli historian of QM Mara Beller published an article in *Physics Today* (1998) titled "*The Sokal Hoax: At Whom Are We Laughing?* She argued in defense of the post modernists, showing that the great architects of quantum theory; Bohr, Heisenberg, Pauli, etc. wrote passages that sound very similar to the kind of stuff that sokal wrote. What sokal wrote does not sound any crazier than what these great scientists were saying when they were trying to explain why quantum theory could not be understood as a picture of reality.

She was a professional, writing in a professional journal, defending the "enemy".

Sokal and a collaborator Jean Bricmont wrote the book *Fashionable Nonsense: Postmodern Intellectuals abuse of Science* (1998)
This book targets Jacques Lacan, Julia Kristeva, Luce Irigaray, and Jean Baudrillard
Sokal and Bricmont say these people, who use scientific terms, do not know what they are talking about.

Sokal's book was reviewed by physicist N. David Mermin in *Physics Today*, April 1999
Mermin said Sokal and Bricmont were not being fair; in context, what these people were saying; the point they were making, is supported by the references to the sciences they make, even though they don't understand the science.

By 2000 the science wars had petered out; not because of exhaustion, but because the luster of post-modernism had dimmed, the storm dissipated within the intellectual community. Postmodernism was no longer a threat to reason and science. A more serious threat now to science in America, as the National Science Foundation and other organizations has been pointing out for years now, is the drop in number of young Americans who are majoring in science and engineering.

However, although no longer called that, the science wars have continued, switching from the intellectual sphere to the judicial sphere, with the religious right challenging the integrity of scientific truth. The challenge remains of accepting that scientific knowledge claims have a historical and socially dependent character; not totally, but the scientific community and their assumptions play significant roles in the formulation of theories which claim to be true.

Lecture 23: Intelligent Design and the Scope of Science

Is intelligent design a scientific hypothesis? Why does it mater? Quite independently of the issue itself, it is intellectually interesting to ask whether the claim that intelligent design is a scientific hypothesis is valuable to us, because examining it helps pull together a number of the core ideas we have discussed on the nature of scientific knowledge. This became an issue in the 21st century, though was still prominent enough that it was featured in a book *Darwin's Black Box* by biochemist Michael Behe in 1996. Behe argues that intelligent design is a scientific hypothesis. The intelligent design position is really a second generation version of the attempt to get creationism taught in biology classrooms.

Courts stopped this attempt, because creationism is a religious doctrine, and therefore does not have the right to be taught as a scientific theory in public schools. In spite of that ruling, about a dozen states restrict in one way or another, the teaching of evolution in the high school classroom. So, the claim that intelligent design is a scientific hypothesis, and not a religious doctrine, implies that it is legitimate material to be taught in a biology class, and is a much more interesting and compelling claim.

This leads to the question: who decides if a hypothesis is scientific? It makes the most sense if evolutionary biologists are the ones that decide. If this community fails to recognize it as a scientific hypothesis, then it is not, even if they are wrong. It has nothing to do with are they right or wrong; how could we know they are right or wrong?

What criterion would we apply:
* Explanatory power in the context of the scientific study of natural phenomena
* Predictive success
* Some kind of control (even Einstein's General Theory of relativity can be "controlled for": GPS systems need to correct for the effect of the earth's mass and motion.
* testable/verifiable (can't test for or verify existence of "dark matter")
* open up research program

Intelligent design violates primary criterion of natural philosophy put forward by Adelard of Bath: natural phenomena should only be explained by other natural phenomena.
[OK, God did it, but HOW did he do it?]

Although Intelligent Design as a scientific hypothesis is operationally vacuous, the appearance of design is a legitimate scientific phenomena, and therefore a legitimate scientific observation. Scientists and philosophers for thousands of years have concluded that nature looks designed.

Goldman Does not malign Intelligent Design, he merely criticizes it.

ID is a very intelligent hypothesis, but not a "scientific" hypothesis. Many concur there is a designer.
First philosopher who proposed that design implies designer was Saadia Gaon (882-942)

Moses Maimonides (1135-1204)

St Thomas Aquinas (1224-1274) one of his 5 arguments for the existence of god was design

Many profound thinkers have hypothesized a designer, but few have asserted it was a scientific hypothesis. Design gave compelling reason for believing there was a force behind nature, however, ID is not a useful tool for exploring nature.

Why is ID as a scientific hypothesis so pressing? A misunderstanding on both sides of the dispute on the nature of scientific knowledge, the nature of the "truth" claims that the scientific community makes.
So we have Imperial science clashing with imperial religion.

No theory can have the status of an empirical fact.

At another level,

“Darwinian evolution”: evolution by natural selection acting on random mutations. Behe argues that this is a flawed theory; especially flawed because it cannot explain the “spontaneous emergence” of complex biochemical systems; a mousetrap could not evolve one piece at a time because it is a system of interrelationships; even more so with complex biochemical systems. More like top down design than bottom up evolve. Behe argues for this reason we must turn to ID; top down designer.

Goldman believes this argument is deeply flawed;
It is a version of what since the time of Aristotle has been called an argument from ignorance;
If theory x fails to explain phenomena y, that provides no evidence what so ever for the truth of theory z.

So even if it were true, that Darwinian evolution could not explain the “spontaneous emergence” of complex biochemical systems, that does not automatically mean that ID is true.

Further, it is not at all clear that the biology community as a whole believes that Darwinian evolution can’t do it.

Nor is it an anomaly that to use Kuhn’s term is “critical” (for a paradigm shift)

Other arguments for why there is no crisis:
The science of self organizing systems: inorganic materials self-organize into complicated systems

Complex Technical developments arise spontaneously

Another criticism of Darwinian evolution: it has gaps; but this is part of the evolutionary nature of scientific discovery. Darwinian theory has already evolved; it has been woven into a web with correlated theories in anthropology, geology, ecology, and molecular biology, which is a key test for the value of a scientific theory.

Today is controversy whether natural selection acts only on random mutations; could it act on species, DNA, etc ?

Lecture 24: Truth, History, and Citizenship

Core lessons:

1. The historicity of scientific knowledge: science has a temporal character
It is changing at every level:
data,
analysis; physical instruments or tools, conceptual tools,
assumptions or measures
theories develop and evolve

Goldman is sympathetic to Kuhn's assertion that the history of science is the key to understanding the nature of scientific knowledge. This is exactly what William Whewell claimed in 1830s-40s: *The Philosophy of the Inductive Sciences, Founded upon Their History* (1840)

The "reality" that scientists tell us is out there is totally different today than it was in 1900

The British historian of science Mary Hessa, in the third book of her trilogy: keep in mind that the theories we currently believe to be true are as falsifiable as the theories we look back on as having been falsified. Goldman adds: and the theories we currently hold to be true are as likely to be falsified in the next hundred years as the theories we look back on as having been falsified in the last 100 years.

2. Scientific knowledge is influenced by how scientific knowledge is produced. What scientists know is also influenced by the process through which scientific knowledge is generated. Science is a collective activity. Scientists speak the language of their specialty. Do they invent it?

Galileo believed mathematics was the language of nature

3. The "knowledge problem" (the need to characterize what scientific knowledge is) is itself imbedded in a wider knowledge problem within Western intellectual and cultural history. (Plato vs the Sophists)

The answer of the scientific community to the question of which is true (Knowledge or knowledge) is "yes". science wants to have it both ways. A "realist" character is woven into the rhetoric of science ("this is reality") vs many top rate scientists who have insisted that science is NOT about an independently existing reality; the focus of science is on experience.

Why the ambivalence (or schizophrenia ?)

4. Experience is simultaneously the greatest warrant for realism and for the particular, contingent, and uncertain character of experience.

Plato wants to escape experience, which is hopelessly confusing and contingent, and go to the reality behind experience.

Dewey: Mind and world are aspects of the fundamental reality experience; just as a mountain or a valley are aspects of the fundamental reality earth.
From this perspective the ambivalence of science is understandable. We cant really deny the realist position because it is a direct experience.

Goldman introduces another word beyond reality and experience: actuality

An actuality is a scientific object; like the sun, or an atom. The characteristics of these scientific objects change all the time, which is OK. It is much easier to accept the change the characteristics of a scientific object (actuality) than to accept a change in "reality", which we think of as changeless.

Those scientific objects or actualities are correlated with experience. We are not interested in their connection with changeless "Reality"

The “Real” is unchanging. Scientists who defend the “Realist” fundamental unchanging view do not look at matter; they look at universal constants, that do not change; they look at “invariants”

There is a certain rate of change so that reason is possible; if everything constantly changing and there was no pattern, then could not use reason. So SOMETHING is constant.

This allows us to look at scientific theories as more than just about mere experience,
They are justifiable by a specific set of characteristics: do they explain, do they give us predictive success, do they give us control. We can judge actualities directly, where as we cannot judge reality directly.

Many current issues: climate change, energy issues, stem cell research,
How can science help in developing public policy?
No guarantees about what will happen
Science does not incorporate value judgments about how science is used