PHILOSOPHY OF SCIENCE

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Readings

- M. Curd, J.A. Cover, C. Pincock: *Philosophy of Science: The Central Issues (second edition)*
- Additional readings will be posted on Moodle

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About this course

Some of the main issues in philosophy of science

- Science/pseudocscience
- Theory choice
- Evidence, Confirmation
- Scientific explanation
- Scientific laws
- Realism and antirealism

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About this course

Some central questions about the nature of scientific theory and practice

- What makes a discipline a science?
- What are the **methods** that are supposed to be distinctive of science? Do these methods involve "proving" theories?
- When scientists **choose** between rival theories, is their choice a rational one, or is it more a matter of subjective tastes? Could the choice be made on **rational** grounds? Does science discover the objective truth about the world?

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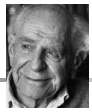

Science and pseudoscience

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Science and Pseudoscience

- The problem about the nature of science: scope, methods, aims
  - Accused to be pseudosciences:
    - Parapsychology, Psychoanalysis, Astrology, Creation science …
  - They are outside (and kept outside) the scientific community:
    - They do not publish in scientific journals; they are not funded by state or scientific agencies (i.e.NSF); they are not elected in the National Academy of Sciences…

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Science and Pseudoscience

- "What is the difference between science and pseudoscience?"

Demarcation problem

- Demarcation criteria: Necessary conditions to be a science
  - If they fail → not a science
- PSEUDOSCIENCE: it is said to be scientific but actually it is not
  - Popper, Kuhn, Lakatos, Thagard

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Science and pseudoscience

- The need for a demarcation criterion
  - Creation science was banned from science classrooms for being "pseudoscientific"
  - Would-be research programs are denied funding if they are deemed "pseudoscientific"
  - The authority of science: our community accepts expert testimony from "scientists", but not from "pseudoscientists"

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Scientific method

- The problem:
  - Why should we believe in things science (as opposed to pseudoscience) tells us?
    - Usual answer: scientific method
    - But what exactly is scientific method? Is this the 'empirical method'?
    - (Do we have really reasons to trust the conclusions arrived at via the 'empirical method'?
      - If not, we are in real trouble! ---> more on this later)

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Scientific method: inductivism (the 'empirical method')

Francis Bacon (1561-1626)

- First account of scientific method:
- (naïve) inductivism: The view that scientific theories are arrived at via arguments of the 'enumerative induction to a generalization' form.
  - The dominant theory of the scientific method in the 19th century.
- Scientific laws = 'universal generalizations'.
  - 'Universal generalization':
    - A statement of the form "All things of type A have feature F."

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Inductivism

- Examples of universal generalizations in science:
  - Boyle's Law: For any fixed mass of gas (A), the product of pressure and volume is constant (F)
  - Newton's law of gravitation: For any two bodies (A), the force of gravitational attraction between the two is given by $F=Gm_1m_2/r^2$ (F), where m_1, $m_2$are the masses of the bodies
  - The law of reflection: For any beam of light being reflected from a mirror (A), the angle of incidence is equal to the angle of reflection (F)
  - The law of expansion: All metals (A) expand when heated (F)

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A preliminary problem: Distinguishing good inductive arguments from bad

- Not all arguments of the enumerative-induction form are good arguments.
- Some bad inductive arguments
  - Argument 1: "Proving" that all black people have below average IQ
    - P1: Johnny is black and has an IQ below average.
    - P2: Jamie is black and has an IQ below average.
    - C: All black people have below average IQ.

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A preliminary problem: Distinguishing good inductive arguments from bad

- Argument 2: "Proving" that the sun is in the south in the middle of the day everywhere
  - P1: The sun is in the south at midday in Rome
  - P2: The sun is in the south at midday in Paris
  - P3: The sun is in the south at midday in Chicago
  - C: The sun is in the south at midday everywhere on Earth
- Argument 3 (Russell's analogy): The Christmas Eve turkey - "proving" that it will be fed every day
  - P1: I was fed on December 1
  - P2: I was fed on December 2
  - …
  - P23: I was fed on December 23
  - C: I will be fed every day.

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A preliminary problem: Distinguishing good inductive arguments from bad

- Each of these arguments has a false conclusion. Question: What makes these arguments bad?
  - Argument 1 is bad because it does not rely on enough observations and, perhaps, that the observations it does rely on are not unbiased.
  - Argument 2 is bad because the observations were not carried out under a wide enough variety of conditions.
    - North/South Hemisphere
  - Argument 3 is bad because its conclusion conflicts with another known fact.
    - We know (even if the turkey didn't) that the whole point of bringing the turkey to the turkey farm was to fatten it up for Christmas, and kill it on Christmas Eve.

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Inductivism percisified

- "The principle of induction" :
  - If a **large number** of A's have been observed under a **sufficiently wide variety of conditions**, and if all observed A's have the property F, and if the conclusion that all A's are F's does not conflict with another known fact, it is reasonable to conclude that all A's have the property F.
- Inductivism precisified:
  - Scientific theories are arrived at by *good* enumerative-induction arguments (where the principle of induction tells us what it takes for an enumerative-induction argument to count as a good one).

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The appeal of inductivism

- Inductivism seems to do a good job of capturing:
  - the sense in which scientific knowledge is objective
  - the reason why observations are required to be unbiased and repeatable
  - the role of experience in arriving at scientific knowledge: the premises of the inductive arguments used are observation statements (reports of observations)

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The appeal of inductivism

- Two questions:
  - does inductivism seem to be the method actually used in science?
    - Historical investigation
  - Would induction produce knowledge?
    - More philosophical question

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Problems with inductivism

- Weaknesses of inductivism
  - It does not really describe scientific practice
  - The idea of "objective" observations seems really impossible and/or undesirable
  - It doesn't go beyond the observational level
  - The problem of induction
- So, it cannot be used as an account of scientific method
- Now we will see an alternative: falsificationism

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Problems with inductivism

- 1-The inductivist's instructions are inconsistent
  - Inductivism instructs us to base our enumerative-induction arguments on observation reports that are 'unbiased', i.e. not influenced in any way by theoretical preconceptions.
  - But it also tells us to make sure we carry out observations under a sufficiently wide variety of conditions.
  - And it is the theory that tells us which dimensions of variation it is necessary to test.

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Problems with inductivism

- How do we make these judgments?
  - We rely on background knowledge
  - Such judgments are essential to the practice of science, and they are necessarily influenced by our preconceptions Ex: "all metals expand when heated
    - Relevant variations:
      - Change of metal; Change of heating system
    - Irrelevant variations:
      - Sex of the experimenter; Color of the apparatus; Location of the experiment ; …
    - but how do we judge this or that as relevant or irrelevant ?

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Problems with inductivism

- Also, It might have seemed appropriate at Bacon's time to "free our minds" in order to avoid being misled by the current wisdom.
- But nowadays scientists are building up knowledge upon well established and complex theories and it does not make any sense for them to ignore them!
  - Example: the telescope findings rely on the truth of optics

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Problems with inductivism

- 2-The inductivist account does not fit the actual scientific practice
  - A difficulty: History of science has been told by an inductivist perspective
  - An example that seems to support the inductivist account
    - Newton's own account of his work: laws are inferred by the data (Kepler's laws)
    - But this cannot be right: Pierre Duhem (1861-1916) (see later)
    - Because each planet exerts a gravitational force on the others, the ellipses are not perfect. So, Newton could not have inferred his law from Kepler's laws

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Problems with inductivism

- Another example that seems to support inductivism:
  - Brahe made new observations and Kepler used them to formulate his laws.
  - However, Kepler was unable just to read off the laws from the data. Rather, he was motivated to search for a reasonably simple pattern to planetary motion by his somewhat mystical belief in a mathematically elegant form to the motion of the planets

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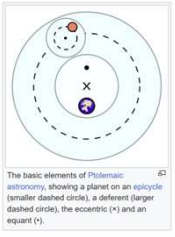
Problems with inductivism

- A counterexample to inductivism:
  - Copernicus was motivated to his theory NOT because of new data but mostly because he did not like the equant!!!



The basic elements of Ptolemaic astronomy, showing a planet on an epicycle (smaller dashed circle), a deferent (larger dashed circle), the eccentric (×) and an equant (•).

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Problems with inductivism

- 3-Inductivism cannot account for theories that "go beyond the observational level:"
  - The conclusion of an enumerative-induction argument is always an empirical generalization. As a result:
    - 1-Inductivism cannot account for scientific laws that say only what would happen under 'ideal' conditions
      - e.g. Newton's First Law: Any object that is not acted on by an external force moves at constant velocity.
      - Nobody has ever seen (or could ever see) a body that is not acted upon by any external force, so this law cannot possibly be the conclusion of an enumerative-induction argument grounded in observation.

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Problems with inductivism

- As a result:
  - 2-Inductivism cannot account for scientific laws that involve concepts that go beyond observation (theoretical entities)
    - E.g. Newton's Second Law: F = ma.
    - Newton claimed to have inferred his laws from Kepler's laws of planetary orbits.
    - But Kepler's Laws involve only positions, distances, areas and time intervals, whereas Newton's Laws involve the new concepts of force and mass are not observable (they are theoretical entities).
    - So, Newton's laws cannot possibly be obtained as the conclusion of an enumerative-induction argument from Keplerian observation reports.

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Problem with inductivism

- 4-A devastating problem for inductivism: *The problem of induction*
  - P. of I.: there is no non-question begging justification of induction
  - According to inductivism, scientific theories are arrived at via inductive arguments
  - If beliefs formed in that way are not justified, then, to whatever extent inductivism is true, *beliefs formed via the scientific method are not justified beliefs*

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Problem with inductivism

- Hume's argument:
  - The (enumerative) inductive inference (DATA)→(THEORY) is not deductively valid
    - Deductively valid argument: if the premises are true, the conclusion must be true
    - Almost by def. induction is not deductively valid
      - Eg:
        - All swans observed so far are white
        - So, all swans are white
          - Not deductively valid: it is possible for a swan to be non-white

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Problem with inductivism

- Maybe we can turn this inference in a deductive argument, adding a premise P, so that P+(DATA)→(THEORY) is deductively valid (P="The future will be like the past")
  - Eg:
    - All swans observed so far are white
    - P:The future will be like the past
    - So, all swans are white

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Problem with inductivism

- Are we justified in assuming P (="the future will be like the past") to be true?
  - P is not a relation of ideas, so it is not a priori
    - P is not like "all bachelors are unmarried males"
  - P is not true because it was observed to be true
    - It is about the future
    - Rather, it is an **unobserved matter of fact**…

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Problem with inductivism

- …Knowledge of unobserved matters of fact must come from induction
- So, P should be justified through induction
- But P is present in every inductive arguments as a premise
- So, the inductive argument for P is circular

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Problem with inductivism

- Generalizing P:
- UN= principle of uniformity of nature= if a given regularity has held in the past, then it will continue to hold also in the future
- Same problems to justify UN as we had to justify P

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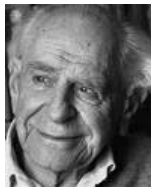
FALSIFICATIONISM



Karl Popper
(1902-1994)

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Falsificationism

- Popper's project
  - To find an account of scientific method that does not require induction
  - To find a neat answer to the question "What is the difference between science and pseudoscience?"
    - Demarcation problem
    - PSEUDOSCIENCE: it is said to be scientific but actually it is not
      - How can we tell?

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Falsificationism

- 18th century: success of Newtonian mechanics, chemistry, physiology
- The next step is to apply the same method to the discovery of the laws of human behaviour and of societies:
  - Marxism and Psychoanalysis- theories of the social and psychological nature of human beings that were claimed to fulfill the purpose of a genuine science

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Falsificationism

- Marx's theory of history
  - The Marxist theory of history claims to provide the principles underlying the development of human societies.
  - Historical episodes are to be explained in terms of class struggles.

Karl Marx (1918-1883)

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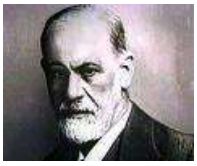
Falsificationism

- Freud's psychoanalysis-
- the unconscious governs the behaviour of human beings and their interaction



Sigmund Freud (1856-1939)

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Falsificationism

- Adlerian individual psychology-
  - Human actions are to be explained in terms of inferiority feelings.

Alfred Adler (1870-1937)

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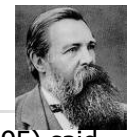
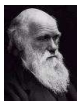
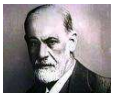
Falsificationism



- Frederick Engels (1820-1895) said this at the funeral of Karl Marx :
  - "Just as Darwin discovered the scientific principles underlying the development of species, so Marx had discovered the scientific principles underlying the development of societies".





- Sigmund Freud compared himself to Darwin and Copernicus

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Falsificationism

- Astrology
  - human destiny is controlled by the positions of heavenly bodies, together with the positions of those bodies on the day and hour of the person's birth.
  - Events of human significance are to be explained in terms of the controlling influences of particular heavenly bodies.

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Falsificationism

- Common feature: **incredible explanatory power**
- Every fact could be explained
- Ex 1: man who pushes a child into the water with the intention of killing him
- EX 2: man who sacrifices his life in order to save a child from drowning
- Freud: man 1 suffered from repression, man 2 achieved sublimation
- Adler: man 1 wanted to prove he could commit a crime, man 2 wanted to prove that he could rescue the child
- Popper: This apparent strength is actually a weakness

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Falsificationism

- If we think that scientific process proceeds by accumulation of positive instances then these theories are scientific…
- …but Popper thinks they are not
- The problem is that it seems too easy to get positive instances for them:
  - They are so general they do not rule out anything.
  - They are so vague that they can be twisted to fit anything (horoscopes)
    - They see confirmation everywhere

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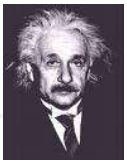
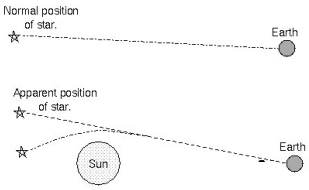
Falsificationism



Albert Einstein (1879-1955)

- Compare with:
  - General relativity
    - Very precise qualitative prediction of the light bending



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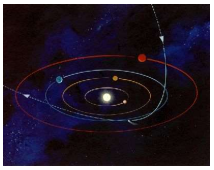
Falsificationism

Isaac Newton (1642-1727)

- Compare with:
  - Newton's theory
    - it predicted that the Halley comet would return in 1758 (every 76 year)



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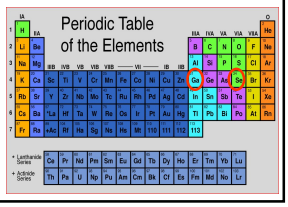
Falsificationism

Dmitri Mendeleev (1834-1907)

- Compare with
  - Dmitri Mendeleev's theory
    - He predicted the existence of Gallium (Z=31) and Selenium (Z=34) (previously unknown) on the basis of the structure of the periodic table



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Falsificationism

- What is the difference between Marxism, psychoanalysis, astrology (pseudosciences) on one hand and General relativity, say, (sciences) on the other?
- **GR is incompatible with certain results; it takes risks by predicting new things that could prove it false**
  - **It is FALSIFIABLE**

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Falsificationism

- **Popper's answer to the demarcation problem: sciences are *falsifiable*; pseudosciences are not**
  - Falsifiability: a theory is falsifiable if it makes definite predictions that might be shown to be false

Deductive reasoning:

T→ E
~E

~T

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Falsificationism

- Confirming evidence (basic idea):
  - the more evidence is compatible with the theory, the more one is justified in believing in the theory
  - Popper: confirmation should not be accepted unless it can be shown the test was a serious but unsuccessful way to falsify the theory
    - corroborating evidence

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Falsificationism

- Two kinds of falsificationism:
  - 1-F. as a logical property of statements scientific theories
    - Genuine scientific theories make precise predictions and imply at least one testable prediction
  - 2-F. as a methodological term prescribing how scientist should behave
    - Scientist should test their theories and if they turn out to be falsified they should abandon them

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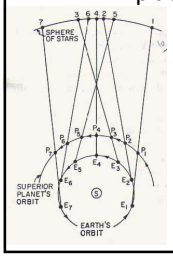
Falsificationism

- This criterion seems(?) to draw the science/pseudoscience line in the right place:



- Sciences
  - Astronomy:
  - it predicts that Mars will continue to retrogress every 687 days. If this had stopped happening, we would have had to conclude that the theory itself was false.
  - So, astronomy is falsifiable.

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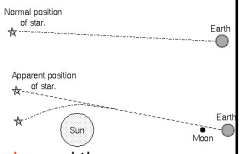
Falsificationism



- Sciences:
- Einstein's relativity:
  - Relativity predicted that light would bend around the sun.
  - If Eddington's 1919 expedition had found that light did not bend around the sun, we would have had to conclude that relativity was false.
  - The prediction was risky: it could have been shown to be false (and there was no reason to expect the prediction to be true, apart from relativity theory).
  - There would have been no way for Einstein to worm out of the conclusion that his theory had been proved false, if Eddington's expedition had returned with the opposite data.
  - So, relativity is falsifiable.

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Falsificationism

- Pseudo-sciences - How they typically fail the falsifiability test:
  - Astrology:
  - Fails 1: The theory's predictions are so vague that they can never be shown to be false.
  - Fails 2: Astrologers focused too much on their successes that they were unimpressed by the data that did not fit

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Falsificationism

- Marxism:
  - Respects 1: Early versions were testable, and indeed they have been falsified, but
  - Fails 2: Marxists reinterpreted the evidence to make it agree with the theory
    - Example of falsifying evidence:
      - Prediction: all socialist revolutions will occur among the proletariat of industrialized countries
      - Falsification: China and Russia were pre-industrial

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Falsificationism

- Another example:
  - Many measures to safeguard the safety of workers were introduced in England in the 19th century
  - This contradicts Marxism: the ruling class has no interest in ensuring decent living for the poor
  - Yet some Marxists have argued that such introduction actually confirms Marxism since they show that the capitalists were aware of the imminence of the revolution and were trying to placate the workers

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Falsificationsm

- Psychoanalysis:
- Simply not testable – it's more like a myth than a theory
  - Since there is no possible observation that the theory would not be able to 'explain', there is no situation in which observation would force us to say that the theory was false.

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Falsifiability precisified

- To define 'falsifiability', we first need to define 'basic statement'.
- Basic statements...
  - ...are supposed to be reports of possible observations
  - an 'observation' is taken to be something publicly accessible (so, *not* a report of private 'sense-data').

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Falsifiability precisified

- Popper's official definition of "basic statement":
  - Singular existential statements ("There exists a ...")
  - Assert the existence of a particular type of thing or event in a given space-time region

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Falsifiability precisified

- Examples of basic statements:
  - There is a giraffe in room 204 at 8pm.
  - The pointer on the lab apparatus in room 101 at 2pm was pointing to the number 6.
  - The tiger killed the deer next to tree number 59 at 8pm.



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Falsifiability precisified

- Basic statements are supposed to report (possible) *observable* events.

"The hand of God guided the woman's hands on the steering wheel beside the cliff at 6pm" is not falsifiable, because the guidance of 'the hand of God' is not an event that can be *observed*.

- Basic statements are supposed have the feature that two suitably placed observers would agree about the truth-value of the statement.

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Falsifiability precisified

- Definition:
- A given basic statement is a *potential falsifier* of a given theory iff [= if and only if] the negation of that basic statement is entailed by the theory.
  - A="it is not the case that light bends around the sun"
  - ~A="Light bends around the sun"
- Definition:
- A statement is falsifiable iff it has at least one potential falsifier.

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Falsifiability precisified

- Examples of falsifiable statements:
  - No giraffes will walk into this room in the next 10 minutes.
  - All copper conducts electricity.
  - …

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Falsifiability precisified

- Examples of statements that are *not* falsifiable:
  - Either it is raining, or it is not raining.
  - God has no cause.
  - All bachelors are unmarried.
  - It is logically possible that space is infinite.

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The falsificationist account of scientific reasoning – the Hypothetico-Deductive (HD) model

- Propose a hypothesis.
- Try to deduce predictions from that hypothesis, with the feature that some possible observation (as reportable in a basic statement) could show that the prediction is false (i.e. try to find *potential falsifiers* of the theory).
- If it is not possible to find any such predictions, the theory is unfalsifiable, and so is not scientific.
- If such a prediction is found, design an experiment to test the prediction.
- If the prediction turns out to be false, the hypothesis has been proven false (= *falsified*).
- If the prediction turns out to be true, the theory has been *corroborated*.

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The falsificationist account of scientific progress

- When a theory is falsified, it should be replaced by a theory that entails all the true basic statements entailed by the old theory, and that in addition has some potential falsifiers that were not potential falsifiers of the old theory. (The more potential falsifiers the better. Falsificationists prefer "bold conjectures".)

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The falsificationist account of scientific progress

- Example: progress in physics from Aristotle to Einstein
  - Aristotelian physics
    - correctly predicted that (true potential falsifiers of the theory)
      - heavy objects would fall to the ground
      - it would be possible to lift water using a liftpump.
    - BUT incorrectly predicted that
      - the moons of Jupiter would orbit the Earth.

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The falsificationist account of scientific progress

- Example: progress in physics from Aristotle to Einstein
  - Newtonian physics
    - correctly predicted that
      - heavy objects would fall to the ground,
      - it would be possible to lift water using a liftpump
      - the moons of Jupiter would orbit Jupiter
    - made correct novel predictions:
      - e.g. the synchrony between the tides and the position of the moon
    - BUT incorrectly predicted that
      - the [inertial] mass of fast-moving bodies would be independent of velocity

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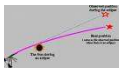
The falsificationist account of scientific progress

- Example: progress in physics from Aristotle to Einstein
  - Relativity
    - correctly predicted that
      - heavy objects would fall to the ground,
      - it would be possible to lift water using a liftpump,
      - the moons of Jupiter would orbit Jupiter,
      - the synchrony between the tides and the position of the moon
      - the [inertial] mass of fast-moving bodies would be independent of velocity



    - made correct novel predictions:
      - the bending of light
    - ...?

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The appeal of falsificationism

- Seems to capture what's 'bad' about astrology etc.
- Uses only deductively valid argument forms.
- Seems to get the logic of experimental testing of theories right.

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Falsificationsm

- Recall - Two kinds of falsificationism:
  - 1-F. as a logical property of statements (scientific theories imply at least one testable prediction)
  - 2-F. as a methodological term prescribing how scientist should behave (scientist should test their theories and if they turn out to be falsified they should abandon them)
  - Ex- Marxism can be testable but still Marxists would not abandon the theory even if it has been falsified
    - Prediction: all socialist revolutions will occur among the proletariat of industrialized countries
    - Falsification: China and Russia were pre-industrial

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Problems with Falsificationsm

- Critics of the logical sense
  - *It is too weak, maybe it is just a necessary condition but not sufficient*:
    - Take a crazy statement C like "aliens visited earth during the Pleistocene and removed all the traces of their visit"
    - C does not make any testable prediction
    - T&C makes a lot of prediction (all those of T)
    - Because of this T&C satisfies Popper's criteria, so it is a science, but this does not make a lot of sense

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Problems with falsificationism

- *Some legitimate parts of science seem not to be falsifiable*
  - Probabilistic statements
    - Many theories in science do not make any definite predictions: they only predict probabilities.
      - e.g. According to atomic theory, any given phosphorus-32 atom has a probability of ½ of decaying within the next 15 days.
      - An experiment to find out whether or not a given phosphorus-32 atom does decay within 15 days
      - There are two possible outcomes of this experiment: either the atom decays, or it doesn't.
      - But neither outcome is incompatible with the theory!
      - So, there is no possible outcome that will falsify the theory.

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Problems with falsificationism

- A possible fix: allow the theory to count as 'falsified' if some outcome is observed that, according to the theory in question, is (not impossible, but) very unlikely.
  - E.g. Suppose that, according to atomic theory, any given quickium atom has a probability of 99.999% of decaying within 3 seconds.
  - Suppose that we do the experiment, and the atom does not decay.
  - This would be incredibly unlikely if the theory were true, but not particularly puzzling if the theory is false.
  - So perhaps we could count passing tests like this as 'corroborating' the theory.

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Problems with falsificationism

- *Some legitimate parts of science seem not to be falsifiable (cont'd)*
- Existential statements
  - 'Existential statements': statements of the form '_____ exists'
  - Examples:
    - Atoms exist
    - Black holes exist
    - DNA exists
    - Viruses exist

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Problems with falsificationism

- Suppose we do an experiment designed to look for viruses (e.g. looking through a microscope), and we don't find any.
  - This doesn't prove that viruses do not exist.
  - Indeed, it doesn't seem that anything would prove that viruses don't exist.
  - So, existential statements seem to be unfalsifiable.

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Problems with falsificationism

- *Some legitimate parts of science seem not to be falsifiable (cont'd)*
- Unfalsifiable scientific principles
  - The principle of conservation of energy
  - The second law of thermodynamics
  - Virtually no scientist will be willing to specify a possible sequence of observations such that, if those observations were made, she would give up the principle in question. So, scientists seem to treat these principles as unfalsifiable. But they are surely scientific…

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Problems with falsificationism

- Critics of the methodological sense: Kuhn, Lakatos (see later)
- *Scientists don't reject falsified theories (and they seem to be right not to)*
  - Examples:
    - The Ptolemaics (and early Copernicans!) did not reject their theories when the quantitative predictions came out wrong – they spent centuries fiddling with the epicycles.
    - Newtonian mechanics and the problem of Uranus

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Problems with falsificationism

- Popper's reply: Modifications to save a theory from falsification are acceptable, *as long as the modifications are not 'ad hoc'.*
  - The intuitive idea behind saying that a modification is "ad hoc": it has no possible motivation other than an ill-conceived desire to save the theory, and it's somewhat implausible.

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Problems with falsificationism

- Popper's technical definition of "ad hoc:"
  - An 'ad hoc' modification of a theory is a modification that does not 'add empirical content' to the theory.
  - i.e. the modified theory must have some potential falsifiers that were not already potential falsifiers of the unmodified theory.
    - The postulation of Uranus was not 'ad hoc'.
    - Example of an 'ad hoc' modification: The Aristotelian's reaction to Galileo's observation of craters on the Moon (to show the Moon's imperfection)
      - Craters are a sign of contamination of the Moon by Earth elements (in contrast with the higher spheres, which are perfect)

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Problems with falsificationism

- A further problem:
- *Sometimes, scientists will not even modify the theory; they will just tolerate the 'falsifying' observation for decades* or centuries, until someone either
  - (a) comes up with a modification that saves the theory from falsification, or
  - (b) comes up with a new theory.
- And this seems to be perfectly rational, too.

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Problems with falsificationism

- Why should we *want* theories that are 'falsifiable' in Popper's sense?
  - A natural response would be: Falsifiable theories rule out more. So, they tell us more about the way the world is. We want to know as much as possible.
  - But this doesn't help us if 'corroboration' does not have anything to do with believing that the theory's predictions are probably true.
  - Other suggestions??

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Problems with falsificationism

- The ambiguity of falsification: *crucial experiments are impossible*
  - Duhem's point (see later)

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Science and pseudoscience

- After Popper
  - Popper aimed to demarcate science from pseudoscience by means of his 'falsifiability' criterion.
  - In criticizing falsificationism, we've given a number of reasons for thinking that this criterion doesn't draw the line in the right place.
- Kuhn, Lakatos and Thagard each try to supply a better demarcation criterion

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Kuhn's account of science

- "Normal science" vs. "revolutionary (or extraordinary) science"
  - Normal science
    - ... is the **norm** (i.e. most science is 'normal science').
    - Occurs when there is only one theory (or "paradigm") being taken seriously by the research community, and that theory is regarded as basically correct.

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Kuhn's account of science

- During normal science:
  - The community discourages questioning of the fundamental assumptions of the theory.
  - Scientists aim to "solve puzzles" within the framework of the existing theory
    - Deducing predictions from the theory
    - Reconciling recalcitrant data with the theory
    - Resolving apparent paradoxes within the theory.
  - If a scientist fails to solve such a puzzle, this is counted as a failure of the *scientist*, not of the *theory*.
  - Example of a period of 'normal science': Ptolemaic astronomy 200-1500 AD (i.e. before Copernicus came along)

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Kuhn's account of science

- Revolutionary science
  - Occurs when there is more than one theory on offer, and/or when there are so many unsolved and apparently unsolvable problems within the currently dominant theory that scientists start to look elsewhere.
  - During revolutionary science
    - Scientists are faced with a choice between competing theories.
    - The fundamental assumptions of each theory may be questioned.
    - The 'unsolvability' of a puzzle *may* be regarded as the fault of the theory.
    - Recalcitrant data may result in the rejection of a theory.
  - Example of a period of 'revolutionary science': astronomy c. 1550-1650 AD, during the fight between Ptolemaics and Copernicans

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Kuhn's objections to Popper

- 1) Kuhn's objection to Popper
  - Popper's 'falsificationism' is *at best* a description only of "revolutionary science" [and isn't even that].
  - But *most* science is "normal science".
  - So Popper's criterion *at best* regards only a *minority* of scientific activity as genuinely scientific.

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Kuhn's objections to Popper

- Popper: Astrology makes vague predictions so in order to escape falsification it destroys its own testability
- 2) Kuhn's objection to Popper:
  - It is historically false that astrology does not make predictions:
    - There have been predictions and they have been falsified
  - Astrologers explained failure by saying that the issue was complex
    - It was just **after** astrology became implausible that these arguments seemed question begging
    - Compare with meteorology or medicine

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Kuhn's objections to Popper

- 3) Kuhn's objection to Popper:
  - History tells us that there have been theories that have been replaced by a new theory before they were falsified
    - Ex: Copernicus proposed his alternative to Ptolemaic astronomy long before there was any experiment which was problematic for Ptolemaic astronomy
      - Galielo's observation happened 60 year after
      - Newton's Principia was published in 1687

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Kuhn's demarcation criterion: "puzzle solving"

- Kuhn's demarcation criterion
  - The theory must be associated with a "puzzle-solving tradition"
    - i.e. there must *be* a period of "normal science" developing the theory in question.
  - According to Kuhn, astrology is a pseudoscience because astrologers **never had puzzles to solve**. (Contrast with astronomy: checking data, adjusting epicycles etc.)
    - "[W]ithout puzzles, able first to challenge and then to attest the ingenuity of the individual practitioner, astrology could not have become a science even if the stars had, in fact, controlled human destiny."

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Kuhn's demarcation criterion: "puzzle solving"

- The real problem with astrology & CO. is that they had no puzzles to solve
- Compare with the astronomer:
  - More than a millennium of puzzles in astronomy helped shape astronomy in what it is
  - No puzzle at all in astrology – failures did not give rise to research puzzle to constructively attempt to revise the astrological tradition

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Lakatos' view

- Lakatos's paper ("Science and pseudoscience"):
- Genuine scientific knowledge **cannot** be marked off from impostors simply in terms of:
  - 1-The Number of people who believe in X
    - A lot of people have believed in something which we think is pseudoscientific

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Lakatos' view

- 2-The assertion that science is supported by observation: (like Kuhn and Popper) theories cannot be deduced from observational facts
  - Theories are unprovable: It is possible that all our observations are correct and, say, Newtonian mechanics is false since some object we did not observe yet might fail to obey Newton's law
    - "all As are B" cannot be deduced from "some As are B"

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Lakatos' view

- Theories are equally improbable:
  - There are infinitely many ways the world could be, and all of them are equally probable:
    - 1 obeys Newton's law (N) but all the others do not
    - 1 and 2 obey N but all the others do not
    - 1,2 and 3 obey N but all the others do not
    - …
    - All bodies (1, 2, …, n, …) obey N
  - There possibilities are infinite so the probability of each must be zero
  - Therefore, the probability of the last one (= the probability of N being true) is zero too.

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Lakatos' view

- An attempt to fix:
  - even if the initial probability is zero, it grows over time when the theory has been "confirmed"
- Why it does not work:
  - Bayes' theorem- how one should update the probability of T in light of the evidence E: P(T/E)
    - P(T/E)=P(E/T)*P(T)/P(E)
  - If the initial probability P(T) is zero, the whole fraction is zero.

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Lakatos' objections to Popper

- 1) According to Popper's criterion, whether or not a theory is scientific has nothing to do with how much evidence there is (or isn't) for it.
- Rather, Popper's criterion has to do with how scientists working with that theory react to 'falsifications'.
- So, Popper's demarcation is **not** between ***theories***; it is between ***attitudes to theories***.

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Lakatos' objections to Popper

- 2) All theories face some unsolved problems.
- So, technically speaking, they are all immediately 'falsified'.
  - "All theories... are born refuted and die refuted. **But are they equally good?"**

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Lakatos' criterion: degenerating vs. progressive research programmes

- 1-**"Hard core":** the theory's most fundamental principles
  - Example:
  - The three laws of Newtonian Mechanics

Lakatos' criterion: degenerating vs. progressive research programmes

- 2-**"Protective belt":** a collection of auxiliary hypotheses and assumptions about the initial conditions
  - The scientist is more willing to adjust these than to abandon the "hard core" of her theory
    - Example:
    - Details of the number and the masses of the planets

Lakatos' criterion: degenerating vs. progressive research programmes

- 3-**"Positive heuristic":** 'A set of ideas about how to solve problems and respond to anomalies'
  - [Not entirely clear what this is supposed to mean]

Lakatos' criterion: degenerating vs. progressive research programmes

- We should think to theories not as frozen in time but as historically extended scientific research programmes, and we should evaluate them on this basis
  - Scientific theory iff progressive research programme
  - Scientific change/progress: result of competition with rival programme(s)

Lakatos' criterion: degenerating vs. progressive research programmess

- In a ***progressive*** research programme, the enterprise of trying to reconcile new data with the hard core, etc, leads fairly frequently to *successful novel predictions*.

Lakatos' criterion: degenerating vs. progressive research programmes

- Examples:
- Halley's prediction (based on Newtonian theory) that a certain comet would return 76 years later
- The prediction (based on Newtonian theory) of the existence of Neptune
- Einstein's prediction (based on general relativity) of light-bending

Lakatos' criterion: degenerating vs. progressive research programmes

- A ***degenerating*** research programme is one that has long since stopped making successful novel predictions (or that never made any in the first place).
  - "What really count are the **dramatic, unexpected, stunning** predictions... where the theory lags behind the facts, we are dealing with miserable degenerating research programmes."

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Lakatos' criterion: degenerating vs. progressive research programmes

- Examples:
  - Marxist history
    - Made several bold predictions that failed, and gave several after-the-fact 'explanations', but never made a single successful novel prediction in advance.
  - Astrology
    - Also provides only vague predictions and after-the-fact explanations but no novel predictions

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Lakatos' criterion: degenerating vs. progressive research programmes

- Lakatos on scientific revolutions
  - The scientists will tend to join the progressive research programme
  - Against Popper: scientific revolutions happen only when there is an alternative theory
  - Against Popper and Kuhn: scientific revolutions are not sudden, they take time
  - Against Kuhn: scientific revolutions are not irrational (see later). Rather, the progressive research programme replaces the degenerating one.

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Thagard's account

- Bart Bok, Lawrence Jerome, Paul Krutz (1975) attack on astrology as a science:
  - 1- It originated by part of the magical world-view
  - 2-The planets are too distant to give a physical foundation to astrology
  - 3-People believe in it out of longing for comfort

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Thagard's account

- Thagard: not good reasons
  - 1, 3- origins and psychology of popular belief are irrelevant for scientific status
    - Ex: see alchemy and chemistry
  - 2- lack of physical foundation does not make X unscientific
    - Ex: continental drift, smoke and cancer

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Thagard's objections to everybody else

- Thagard's objection to Kuhn: Astrology does have puzzles (at the level of horoscopes):
  - Multitude of influences --> vague predictions
  - Statistical evaluations (Michel Gauquelin)
- but it's still a pseudoscience
  - Because astrologers do little attempt to solve their puzzles (they are uncritical)

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Thagard's objections to everybody else

- Thagard's objection to Lakatos:
  - A nonprogressive programme is pseudoscientific only if maintained against more progressive alternatives
    - There may be times in which the programme is nonprogressive because it lacks competitors

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Thagard's criterion

- Thagard's basic idea: To determine whether a programme is scientific or pseudoscientific, we need to consider *three* types of factors:
  - 'Theory': what is the **theory** itself like?
  - 'Community': how do the '**scientists**' treat their theory?
  - 'Historical context': what **competitor** theories were available?
    - Missing from Lakatos' account

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Thagard's criterion

- "A theory or discipline which purports to be scientific is pseudoscientific if and only if:
  - It has been **less progressive** than alternative theories over a long period of time, and faces **many unsolved problems**, but
  - The community of practitioners makes **little attempt** to develop the theory towards solutions of the problems, shows **no concern** for attempts to evaluate the theory in relation to others, and is **selective** in considering confirmations and disconfirmations."

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Thagard's account

- Why astrology is (now) pseudoscientific:
  - It hasn't changed much since the time of Ptolemy (not progressive)
  - Problems are outstanding
  - We (now) have more progressive theories of personality and behavior (psychology)
  - The community is usually unconcerned with advancing astrology to deal with problems

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Thagard's account

- An objection to Thagard's account
  - Most scientists rejected astrology, calling it 'pseudoscientific', in the 18th century.
  - But we didn't have a progressive program of empirical psychology until the 19th century.
  - So Thagard's criterion would have the consequence that all those scientists were **wrong**. And that (intuitively) doesn't seem correct.
  - So there must be something wrong with Thagard's criterion.

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Some consequences of Thagard's criterion

- 1) some theories (pyramidology and biorhythms) are not pseudoscientific because they lack competitors,
- 2) a theory can be scientific at one time and pseudoscientific at another.

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Some consequences of Thagard's criterion

- 3) Most scientists rejected astrology, calling it 'pseudoscientific', in the 18th century.
- But we didn't have a progressive program of empirical psychology until the 19th century.
- So Thagard's criterion would have the consequence that all those scientists were being irrational.

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Some consequences of Thagard's criterion

- Thangard changed his view in light of these consequences:
- 1-No more necessary and sufficient conditions;
- 2-two new criteria (with one can judge a discipline a pseudoscience without looking for competitors):
  - Pseudosciences often offer highly complicated and ad hoc hypothesis
  - Pseudosciences often use reasoning by resemblance (e.g.: Mars is red, and this it is associated with blood)

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One final possibility

- There is *no* demarcation criterion between science and pseudoscience (not even a *vague* one).
  - But surely there must be *some* difference between scientific progress and "intellectual degeneration"??

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