AC52012

Research Methods

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1. Definitions of science?

Exercise:

- Spend a few minutes writing a definition of science
- Formulate a list of hypotheses, some of which are scientific and some of which are unscientific (state which is which)

- What is the aim of science?
- What is the scientific method?
- What is the purpose of articulating the scientific method?

2. Different types of reasoning

A bit of notation

- *P(m)* - *m* is an object and *P* is a property and *m* has property *P*
- ∀ for all
- → implies
- ∴ therefore
- ∧ and
- ∨ or

A bit of terminology

- *Modus Pon*ens "*the way that affirms by affirming*":

$P \rightarrow Q;$

P

$\therefore Q$

$P(m)$ (1)

$Q(m)$ (2)

$\forall x\,(P(x) \rightarrow Q(x))$ (3)

$P(m)$ (1)

$Q(m)$ (2)

$\forall x\,(P(x) \rightarrow Q(x))$ (3)

Deduction uses *Modus Ponens* to reason from rule (3) and specific case (1), to (2). It is explicative (analytic) and valid (the conclusion necessarily follows from the premises)

$$P(m) \qquad (1)$$
$$Q(m) \qquad (2)$$
$$\forall x\,(P(x) \rightarrow Q(x)) \qquad (3)$$

Induction reasons from many specific cases of (1) and (2), to general rule (3) (It may be an equivalence relation or the implication may be reversed). It is ampliative (synthetic) and invalid (the conclusion does not necessarily follow from the premises).

$P(m)$ (1)

$Q(m)$ (2)

$\forall x\,(P(x) \rightarrow Q(x))$ (3)

Abduction reasons from specific case (2) and rule (3) to a possible explanation for (2), eg. (1). It is ampliative (synthetic), invalid. The conclusion amplifies rather than explicates what is stated in the premises.

$P(m)$ (1)

$Q(m)$ (2)

$\forall x\,(P(x) \rightarrow Q(x))$ (3)

Mathematical induction is deductive reasoning. For a given property *P*, a mathematician would show (2), in order to conclude (3):

1) $((P(n) \rightarrow P(n+1)) \wedge P(0)) \rightarrow \forall x\, P(x)$
2) $(P(n) \rightarrow P(n+1)) \wedge P(0)$ $\therefore$
3) $\forall x\, P(x)$

The car won’t start.

If the battery were dead then the car wouldn’t start

The car won’t start.

If the battery were dead then the car wouldn’t start

Therefore maybe the battery is dead

If it's raining, I'll meet you at the movie theater.

It's raining.

If it's raining, I'll meet you at the movie theater.

It's raining.

Therefore, I'll meet you at the movie theater.

Magic is a basketball player. Magic is tall.

Michael is a basketball player. Michael is tall.

Vince is a basketball player. Vince is tall.

Shaquille is a basketball player. Shaquille is tall.

Magic is a basketball player. Magic is tall.

Michael is a basketball player. Michael is tall.

Vince is a basketball player. Vince is tall.

Shaquille is a basketball player. Shaquille is tall.

Therefore, all basketball players are tall.

Validity and soundness

An argument is said to be *valid* if and only if it takes a form that makes it impossible for the premises to be true and the conclusion nevertheless to be false. Otherwise, an argument is said to be *invalid*.

An argument is *sound* if and only if it is both valid, and all of its premises are *actually true*. Otherwise, an argument is *unsound*.

3. Demarcation

What is the Demarcation Problem?

- The ultimate issue is “how to determine which beliefs are epistemically warranted” (Fuller 1985)

What is pseudoscience?

- The oldest known use of the word "pseudoscience" dates from 1796 when the historian James Pettit Andrew referred to alchemy as a *fantastical pseudo-science* (Oxford English Dictionary). The word has been in frequent use since the 1880's.
- Throughout its history the word has had a clearly defamatory meaning
- An essentially value-laden term has to be defined in value-laden terms

Why does demarcation matter?

- **Theoretical:** helps us to understand the nature of scientific knowledge and methodologies
- **Practical:** pseudoscientific practices might devalue scientific ones; intellectual resources are wasted

Why does demarcation matter?

- Copernicus's theory was banned by the Catholic church in 1616 because it was said to be pseudoscientific. It was taken off the index in 1820 because by that time the Church deemed that facts had proved it and it therefore became scientific.

Why does demarcation matter?

- Creationism - damaged reputation of education in the US
- Homeopathy - can cause physical harm, swindles people out of money
- Paranormal - causes a lot of emotional distress, preys on vulnerable
- Conspiracy theories about AIDS - kills people

Why does demarcation matter?

- Denialism about climate change - may help to bring about a world-wide catastrophe
- Scientology - wreaks havoc on people's lives

Why does demarcation matter?

- Healthcare
- Expert testimony
- Environmental policies
- Science education
- Research funding policies

4. Defining the boundaries of science

- What is the scientific method?
- What is the starting point in science?

Bacon (1561-1626)

- The Baconian method is the investigative method developed by Sir Francis Bacon. The method was put forward in Bacon's book *Novum Organum* (1620)
- Science, unlike pseudoscience, works on the basis of the empirical method.
- The starting point in science is observation and data. From there, go, via induction, to universal generalisation.

Bacon

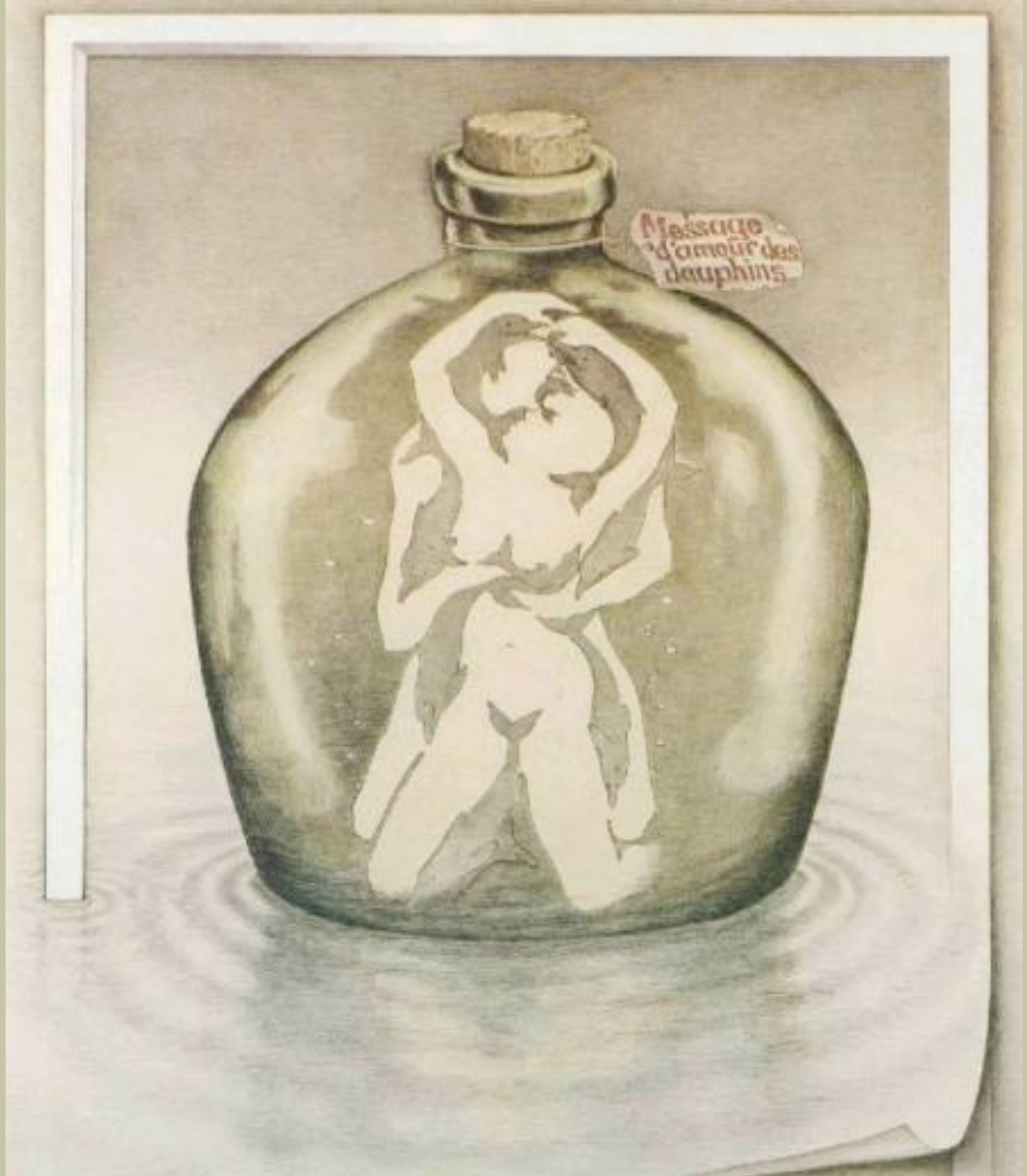
- Theory A is *more scientific than* theory B if:
  - A appears to explain more than B,
  - A has greater coverage than B, and
  - A has higher inductive probability than B

Whewell (1794 -1866)

- We cannot start with bare observation
- Psychological aspects get in the way.

Psychological aspects

- Theory-laden data (bottle)
- Context (checkerboard)
- Perception (basketball)
- The effect of language on thought (crime)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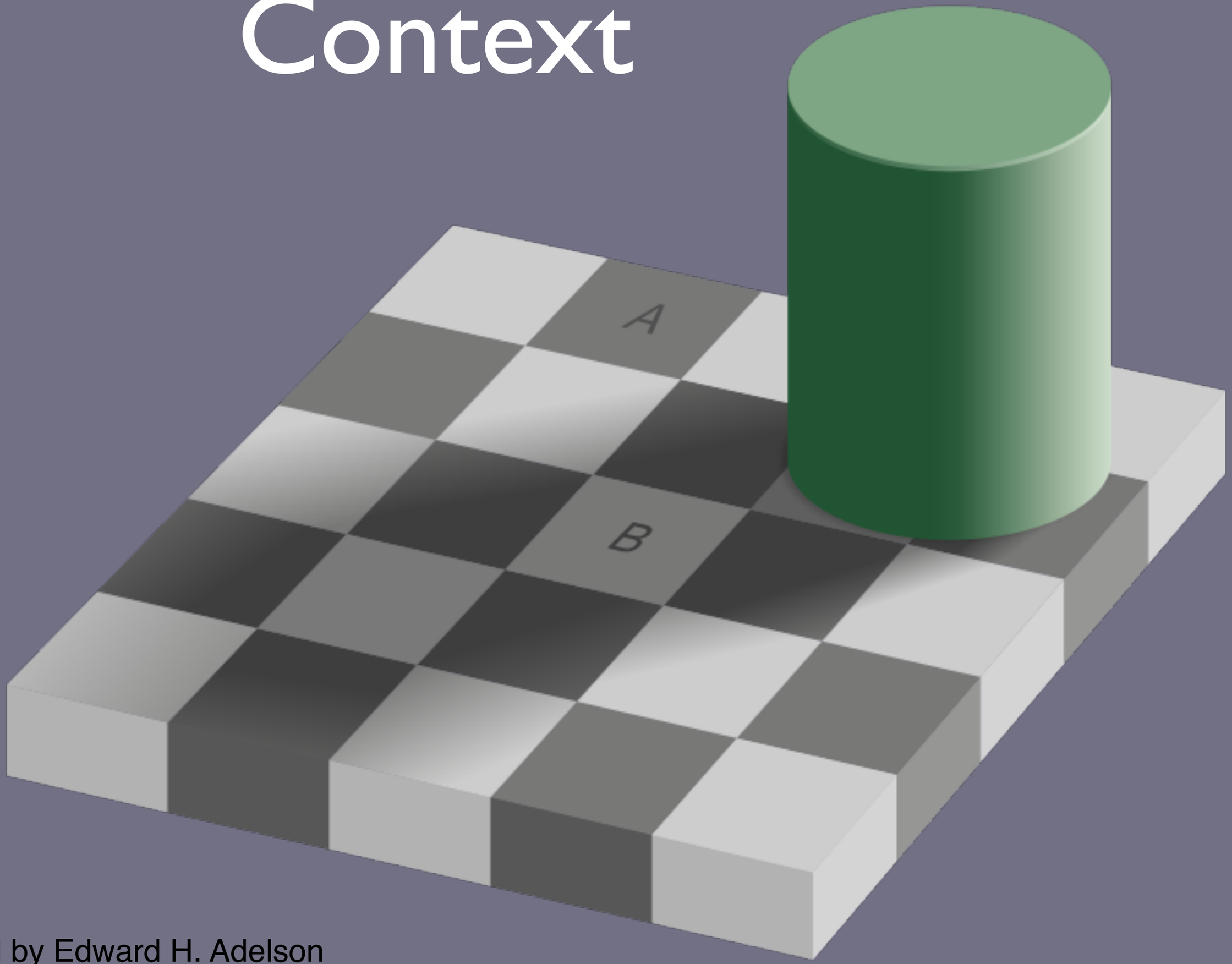
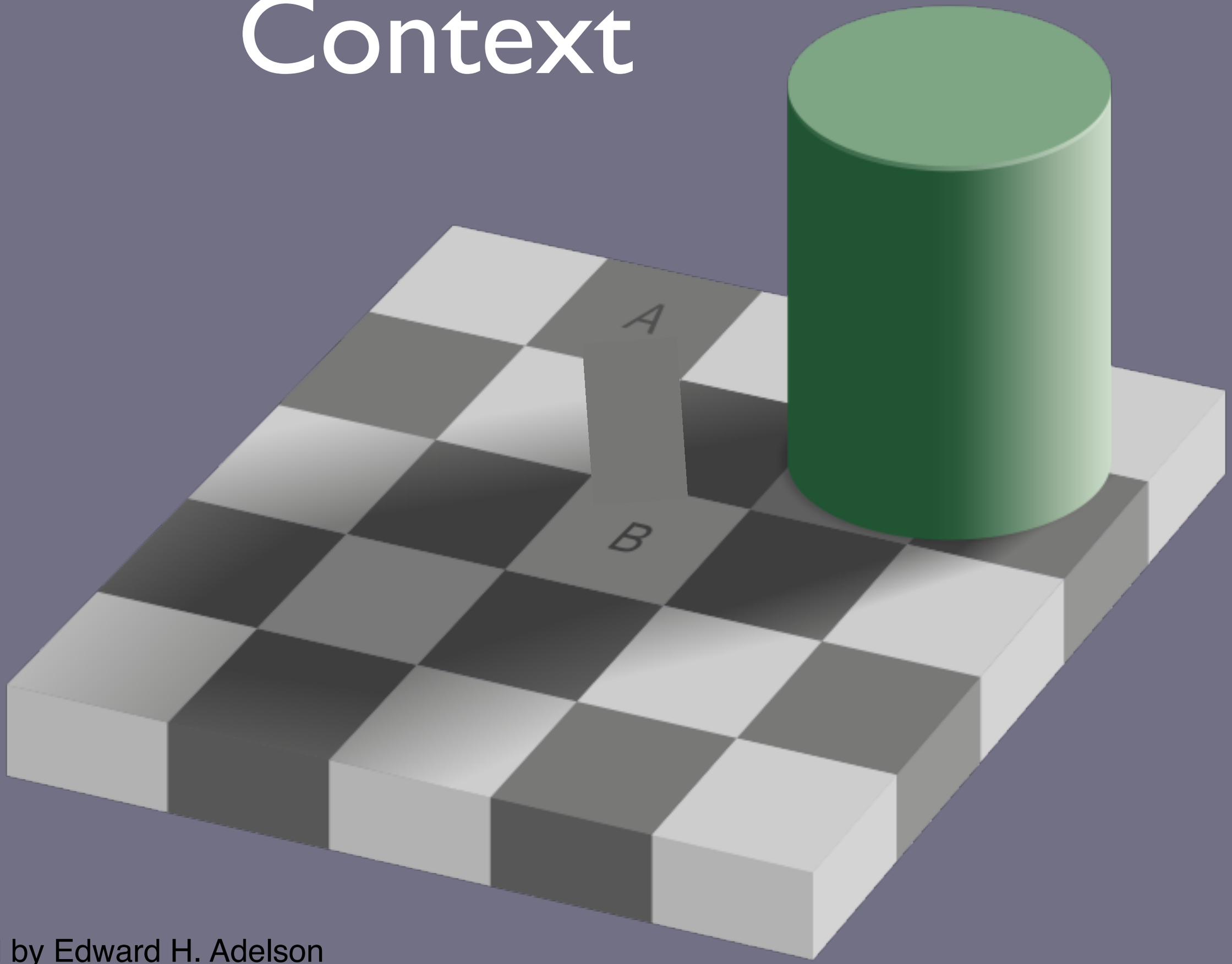


Original by Edward H. Adelson

Context



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Perception

- How many passes can you count in the basketball game?
- https://www.youtube.com/watch?v=vJG698U2Mvo

  Daniel Simons and Christopher Chabris

The effect of language on thought

- Thibodeau, McClelland, Boroditsky - how language affects our reasoning (2009)
- Studied the role of metaphor

Crime as predator

Crime is a wild beast preying on the city of Addison. The crime rate in the once peaceful city has steadily increased over the past three years. In fact, these days it seems that crime is lurking in every neighborhood. In 2004, 46,177 crimes were reported compared to more than 55,000 reported in 2007. The rise in violent crime is particularly alarming. In 2004, there were 330 murders in the city, in 2007, there were over 500.

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Crime as a virus

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- Overall, participants were more likely to suggest an enforcement/punishment solution than a social environment solution (74% enforcement, 23% social environment)
- Participants given the crime-as-virus metaphorical framing were more likely to suggest social reform (31%) than participants given the crime-as-predator framing (20%)
- Only 3% said the use of metaphor affected their decision

Whewell (1794 -1866)

- The starting point is *hypothesis*, rather than observation.

Whewell

Three criteria for a good hypothesis:

1. Novelty: can predict novel phenomena (not just accommodate the phenomena for which it was introduced)
2. Explain a variety of phenomena
3. Coherence: part of a growing body of knowledge (simple, unified, coherent)

Inductivism

Conditions for a good inductive argument

- The number of observations forming the basis of the generalisation must be large
- The number of observations must be repeated under a wide variety of conditions
- No accepted observational statement should conflict with the derived laws

Inductivism

The principle of induction:

If a large number of A's have been observed under a wide variety of conditions, and if all those A's without exception possess property B, then all A's have the property B

Problems

- What is a large number? (is large necessary?)
- What counts as significant variation?
- Little scientific knowledge would survive the demand that there be no known exceptions

Problems

- Much scientific knowledge relates to the unobservable - e.g. protons, electrons, …
- The problem of induction - inductive reasoning can only be justified using inductive reasoning (Hume)

Popper (1902-1994)

- Became disenchanted with the idea that science is special because it can be derived from the facts, the more facts, the better.
- The most forceful advocate of an alternative to inductivism

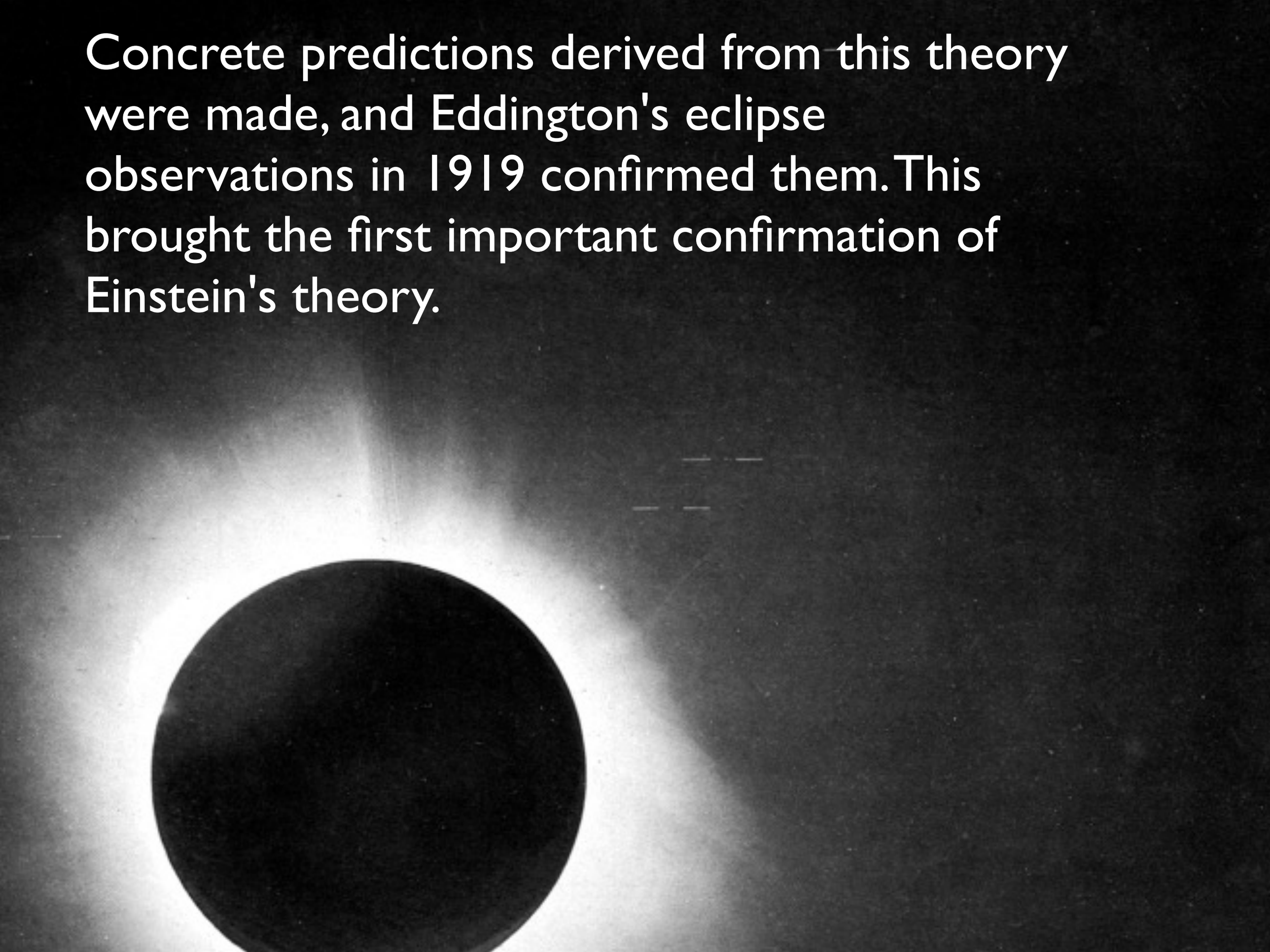
Popper and the Vienna Circle

- After collapse of Austrian empire, revolution in Austria, new and wild theories:
  - Einstein's theory of relativity
  - Marx's theory of history
  - Freud's psychoanalysis
  - Adler's individual psychology

``*A lot of popular nonsense talked about these theories*"

Einstein's theory of general relativity predicts that rays of light should bend as they pass close to massive objects such as the sun

Concrete predictions derived from this theory were made, and Eddington's eclipse observations in 1919 confirmed them. This brought the first important confirmation of Einstein's theory.



LIGHTS ALL ASKEW IN THE HEAVENS

Men of Science More or Less Agog Over Results of Eclipse Observations.

EINSTEIN THEORY TRIUMPHS

Stars Not Where They Seemed or Were Calculated to be, but Nobody Need Worry.

A BOOK FOR 12 WISE MEN

No More in All the World Could Comprehend It, Said Einstein When His Daring Publishers Accepted It.

New York Times headline of November 10, 1919.

- What's wrong with Marx, Freud and Adler's theories? Why are they so different from physical theories - Newton and Einstein's theories?
- ``*I felt that these other three theories, though posing as science, had more in common with primitive myths than with science*" (Popper)

The problem of over-confirmation

- Everywhere you look there is confirmation of Marx's theory. Every conceivable case can be interpreted the light of Adler's theory or equally of Freud's.
- These theories can never go wrong because they are sufficiently flexible to accommodate any instances of human behaviour or historical change as compatible with their theory.

The problem of over-confirmation

- Eg1: A man pushes a child into the water with the intention of drowning it
- Eg2: A man sacrifices his life in an attempt to save the child
- Freud - the first man suffers from repression, the 2nd has achieved sublimination.
- Adler - the first man suffers from feelings of inferiority (perhaps producing the need to prove to himself that he dares to commit a crime). The second man also suffers from feelings of inferiority (perhaps producing the need to prove to himself that he dares to rescue the child).

The problem of over-confirmation

``I could not think of any human behaviour which could not be interpreted in terms of either theory. It was precisely this fact -- that they always fitted, that they were always confirmed -- which in the eyes of their admirers constituted the strongest argument in favour of these theories. It began to dawn on me that this apparent strength was in fact their weakness." (Popper)

The Logic of Scientific Discovery

- We cannot take observations and experiments as the basis of science

The more we learn about the world, and the deeper our learning, the more conscious, specific, and articulate will be our knowledge of what we do not know, our knowledge of our ignorance.

Popper - ***Conjectures and Refutations: The Growth of Scientific Knowledge*** **(1963)**

For this, indeed, is the main source of our ignorance — the fact that our knowledge can be only finite, while our ignorance must necessarily be infinite.

Popper - ***Conjectures and Refutations: The Growth of Scientific Knowledge*** **(1963)**

Popper

- Falsification: no matter how many instances we find, we can still be wrong.
- So we should look for counterexamples
- More secure method

Falsification articulated

- With Einstein it was totally different. There is a risk - he set himself up to be refuted.
- ``*The criterion of the scientific status of a theory is its falsifiability, or refutability, or testability*"

Falsification articulated

- A hypothesis is falsifiable if there exists a logically possible observation statement or set of observation statements that are inconsistent with it, that is, if established as true, would falsify the hypothesis.

Example statements

1. It never rains on Tuesdays
2. Luck is possible in sporting speculation
3. All substances expand when heated
4. Heavy objects such as a brick when released near the surface of the earth fall straight downwards if not impeded
5. When a ray of light is reflected from a place mirror, the angle of incidence is equal to the angle of reflection
6. All points on a Euclidean circle are equidistant
7. Either it is raining or it is not raining

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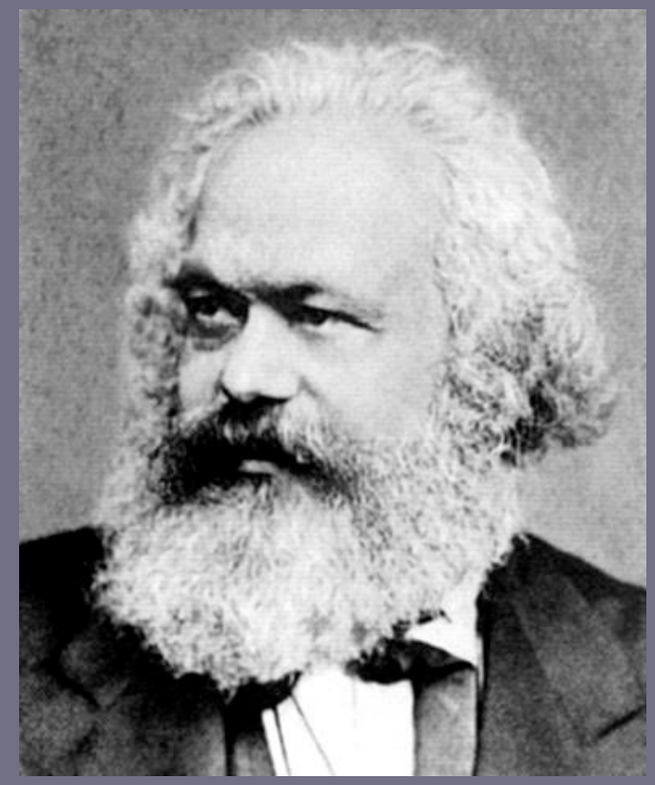
Demarcation criteria

- Scientific = rationally believable
- Scientific theories are falsifiable
- Used as demarcation criteria: scientific theories are falsifiable whereas pseudoscientific theories like Marx's theory of history and Freud's theory of the psyche are not falsifiable - they can accommodate any phenomenon.

Is astrology science?

- Astrology does not pass the test. Astrologers were so greatly impressed and mislead, by what they believed was confirming evidence. By making their interpretations and prophesies sufficiently vague they were able to explain away anything which might have been a refutation of the theory, had the theory and the prophesies been more precise. In order to escape falsification they destroyed the testability of their theory.

Is Marxism science?



- Marxism was initially testable - and was falsified. But it was rescued by its followers by re-interpreting the theory and the evidence. The price of this was that it was now irrefutable - destroyed its much advertised claim to scientific status.

Are the psycho-analytic theories science?

- *"The two psycho-analytic theories were simply non-testable, irrefutable. There was no conceivable human behaviour which would refute them."* (Popper)
- *"I do not doubt that much of what they say is of considerable importance. But no substantially stronger claim to scientific status can be made than for Homer's collected stories from Olympus."* (Popper)

Scientific creationism

- The theory that the world was created in 4004 BC
- Looks like it's in trouble because of the existence of fossils and carbon dating (evidence that the world is much older)
- Solution - God created the world with lots of apparent fossils and apparent evidence that it's older.
- *Ad hoc* maneouver - immune to testing - pseudoscientific

Problems with Popper

- If the aim is to try to falsify one's theories, what should one's attitudes to current theories be?
- Is the function of PoS be to describe or prescribe?
- Many scientists do not try to falsify their theories

Duhem-Quine thesis

- It is impossible to test a scientific hypothesis in isolation, because an empirical test of the hypothesis requires one or more background assumptions

Kuhn (1962)

- *The Structure of Scientific Revolutions*
- Stopped thinking of science as an accumulation of theories
- New picture of science: cycles - pre-science, normal science, crisis, scientific revolutions

Kitcher (1982)

- Three characteristics of science:
  - Auxiliary hypotheses involved in testing scientific theories must be independently testable themselves - independent of the theory it was supposed to protect.
  - Scientific practices are unified wholes - not patchworks of isolated and opportunist methods. They apply a small number of problem-solving strategies to a wide range of cases and problems
  - Good scientific theories are fertile - they open up new areas of research.

Discussion Questions:

- Has your definition of science changed?
- Do you still agree with your lists of scientific and pseudoscientific hypotheses?
- Is demarcation important? (Does it matter whether a given discipline is a science?)
- Is demarcation possible?
- Whose demarcation criteria are most convincing?
- Is there a single scientific method?
- Does science accumulate truths?
- Is Computer Science science?

Reading (optional)

- Karl Popper, *Conjectures and Refutations: The Growth of Scientific Knowledge* (Routledge, 1963)
- Thomas Kuhn, *The Structure of Scientific Revolutions* (University of Chicago Press, 1962)
- Paul Feyerabend, *Against Method* (London: Verso, 1993)
- Mulkay, M. and Gilbert, G. N. *Putting Philosophy to Work: Karl Popper's Influence on Scientific Practice*. Phil. Soc. Sci. 11 (1981) pp. 389-407.
- Paul R. Cohen - *A Survey of the Eighth National Conference on Artificial Intelligence: Pulling Together or Pulling Apart?* CMPSCI Technical Report 91-68
- Alan Chalmers - What Is This Thing Called Science? University of Queensland Press, Open University press, 4th edition, 2013.
- Peter J. Denning - *The Profession of IT* COMMUNICATIONS OF THE ACM April 2005/Vol. 48, No. 4