Lecture 17: How Can Science Make Progress?

Popper and falsification

Karl Popper proposed a way to define science. To him, what separates science from other knowledge-generating systems or methods, is that a scientific theory can be falsified or refuted. Falsification is his *demarcation criterion* (= distinction) that separates science from pseudo-science.

Popper had noticed that some theories were too adaptable to refute through observation. Examples: Freud's theory of psychoanalysis and Marxist theory of history. These theories allow counter-examples to be explained away by referring to the theory, rather than as a sign that the theory does not hold.

Instead of gathering lots of data to confirm our theories, Popper says we should try to find data that would refute them. Only then will we see how strong the theory is. Only the fittest theories will survive. Here is Popper's scientific method:

- Make bold and daring theory/hypothesis that can be falsified.
- Try hard to prove that it is false.
- Replace falsified theories/hypotheses with better ones.
- Test new hypothesis.

Does science make progress in this way? Popper thought so. Even if we cannot prove a hypothesis to be true, we eliminate false ideas. We can also increase our confidence in a hypothesis through testing.

Scientific Paradigms: "the rules of the game"

Thomas Kuhn disagreed with Popper's view on scientific progress. First, this is not how science *actually* works (descriptive). Second, this is not how science *should* work (normative).

In his 1962 book, *The Structure of Scientific Revolutions*, Kuhn argues that science normally happens within a scientific paradigm. A paradigm is a theoretical framework, including scientific methods, research questions, concepts, journals and scientific authorities. Example: Darwin's evolutionary biology.

When we enter a discipline, as students or researchers, we also enter a scientific paradigm. We are taught what the main theory and hypotheses are, what methods we should use, the phenomena and concepts we should talk about, and what counts as relevant and interesting research questions. Research funding will also be determined by the paradigm.

Normal Science as puzzle solving

According to Kuhn, there is not much room to critically discuss this scientific framework within a paradigm. Scientific activity within a paradigm is what Kuhn calls "normal science". This consists in developing the theoretical details of the paradigm and solving remaining problems that the theory faces. Kuhn compares normal science with puzzle-solving. Scientists work to fill in the remaining pieces of the puzzle.

Normal science is not a self-critical stage in the way Popper wanted science to be. Popper thought that one should try to prove theories false. Kuhn argues that it is essential scientific progress to leave time and room for developing a theory in all its details before discarding it.

Scientific activity must therefore be more dogmatic than what Popper suggests. Kuhn even compares normal science to religion. The main theory is trusted, so there is not intention to propose new theories or discover new phenomena. Instead, the goal of normal science is to confirm and develop the theories of the existing paradigm.

Anomalies, ad hoc hypotheses and serendipity

If we always took the first apparent counterexample, or *anomaly*, as a falsification of the theory, we would miss out on important knowledge. Anomalies are empirical problems that reflect a difference between the observed and theoretically expected data.

In normal science, Kuhn argues, anomalies are typically explained away with so-called "ad hoc hypotheses". These are hypotheses that are especially designed to explain why the results were not as expected.

Sometimes new discoveries are made *because* of the discovery of an anomaly. Samantha Copeland referred to this as 'serendipity', or unexpected but valuable discoveries. One example is the discovery of the planet Neptune. Observations showed irregularities in the orbit of Uranus, something that couldn't be explained by Newton's law of gravitation. Instead of falsifying the law, an *ad hoc* hypothesis was put forward that there was a yet undiscovered planet interfering with the orbit, which further observations confirmed.

Crisis and scientific revolutions

A paradigm might not last forever, and scientific theories come and go. A *paradigm shift* happens through a long process, starting with a theoretical crisis and ending in a scientific revolution. At some point, the anomalies to a theory become too many to explain away and the paradigm enters a crisis. At this stage, members of the paradigm begin to question fundamental assumptions. Instead of discussing empirical issues alone, more philosophical debates occur: of methods, ontology, etc.

When a paradigm is replaced by a new paradigm, one cannot just change one thing. Theories, methods and concepts are all part of a larger integrated system. Since normal science is to a large degree dogmatic, Kuhn says that such scientific revolutions cannot happen within the existing paradigm. New generations of researchers must replace the old ones as they 'die out'.

Often a new paradigm will emerge over a long time and piece by piece. An example of a scientific revolution was introduced in Fredrik Andersen's lecture, when Aristotelian physics and cosmology was replaced by modern physics.

Two paradigms cannot compete or be compared

Kuhn compares a paradigm shift with a gestalt switch, where scientists sees the world from a different perspective. Is the new paradigm better than the old one? Kuhn says no and argues that paradigms are *incommensurable*: they cannot be compared to each other. Paradigms cannot compete.

The new paradigm makes the old paradigm irrelevant. Many research questions lose their place in the science. We no longer speak of 4 elements (earth, air, water, earth), the natural place of things or final cause (TELOS), all of which were essential to Aristotle. How, then, does science make progress? According to Kuhn, scientific progress happens only *within* a paradigm, in normal science and its puzzle solving process.

Discussion questions

What is the difference between science and pseudo-science?

What is Popper falsification criterion for science.

How does Popper think that science should make progress?

What do you think about Popper's idea of scientific progress?

What is a scientific paradigm?

What is normal science?

What is an *ad hoc* hypothesis?

How does science make progress, according to Kuhn?

What does it mean that two paradigms are incommensurable?

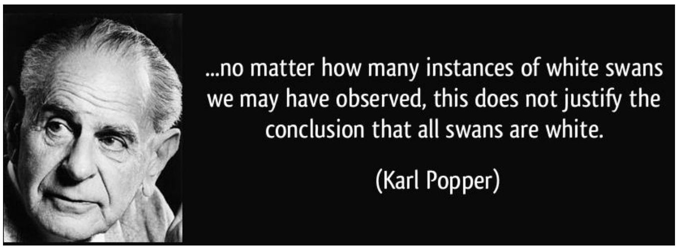
What is Kuhn's criticism of Popper?

Do you think this is a good description of how science is done?

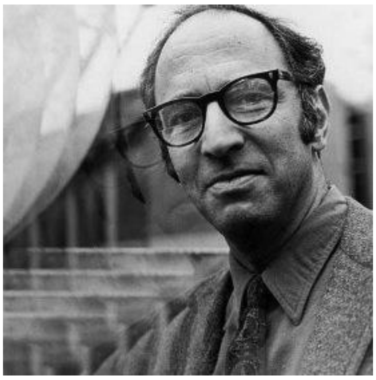
Do you think that normal science is the best way to do science?

What is serendipity?

What role do you think anomalies or counterexamples should play in science?

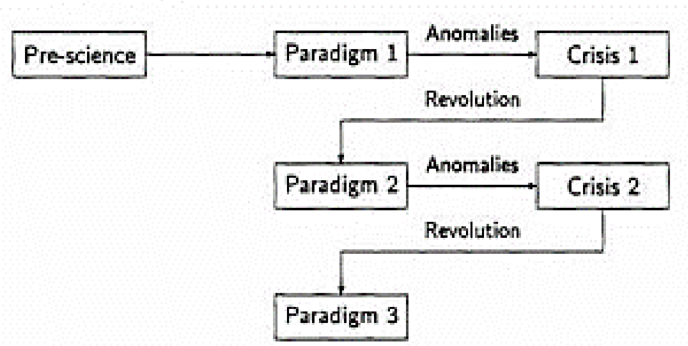


Karl Popper 1902-1994



Thomas Kuhn (1922-1996)

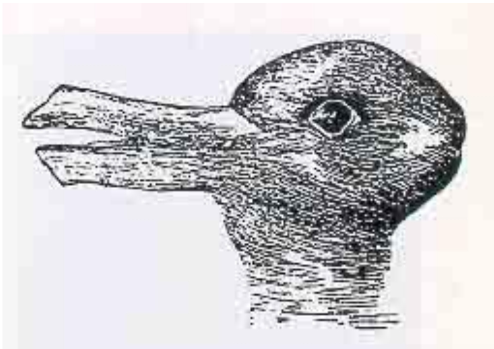
According to Kuhn, science develops from one paradigm to another through crises and revolutions:



Samantha Copeland explained how anomalies, where the expected result does not match the observation, can be important sources of knowledge. Many scientific discoveries happen because some had wisdom to see its potential value: post-it notes (bad glue), Viagra (heart medication), penicillin (mould growing in dirty petri dish). Copeland is the founder of the international Serendipity Society (https://theserendipitysociety.wordpress.com).

Kuhn compared a paradigm shift with a gestalt switch, where one is looking at the same with a new perspective. What do you see?

Duck or rabbit? Same object, two perspectives.



Traditional scientific method versus Popper: