Inductive Reasoning

Martyn Shuttleworth, Lyndsay T Wilson147.1K reads

In science, inductive reasoning is the process of using a series of specific observations to support the probability of a more general conclusion.

Informed by the scientific method, much research conducted today relies at least in part on inductive reasoning to generate and give evidence to theories about how the universe works. Importantly, inductive reasoning never allows us to establish truth with 100% certainty. Rather, we can strengthen the likelihood of a particular conclusion by adding more evidence.

For example, consider the following pieces of evidence (premises):

1. Every known predator has eyes to the front of its skull and not to the side
2. Carnivores lack flat molar teeth
3. A fossil of a mysterious animal has eyes to the front and lacks flat molar teeth

If you were a paleontologist, what would your conclusion be, given the above?

You might conclude: the new fossil is likely that of a carnivorous predator.

Of course, you could be wrong. You could have discovered an exceptional herbivore, or a new kind of animal entirely. Because you are always generalizing and extrapolating, your conclusion is not 100% certain. But it's *probable*.

If another paleontologist discovered that this animal possessed a digestive system characteristic of a herbivore, your conclusion would suddenly be less probable. Hence science proceeds with inductively reasoned, "bottom-up" theories that are stronger or weaker depending on the truth of the premises they rest on.

Inductive vs. Deductive Reasoning

Deduction, in contrast, is a kind of "top-down" reasoning in which we can be 100% certain of our conclusion. Provided that our premises are true, and that the argument is valid (i.e. the conclusion really does follow logically from those premises) then we can accept the conclusion as true.

Deductive reasoning starts with axioms or general principles that are known to hold in that particular domain.

1. All children have mothers
2. Johnny is a child

The conclusion that Johnny has a mother is not just likely here, it is necessarily true. We don't need to conduct any experiments or tests to ascertain this: it is clear just from the logic of the argument. In deductive reasoning, an argument can be invalid (i.e. the conclusion doesn't logically follow – for example, "Johnny has a father") and it can be sound or unsound (i.e. the individual premises are true or not.)

But if the argument is both valid and sound, the conclusion is true.

As you can imagine, deducing truths from general principles is less useful when what you are attempting to uncover is the general principle itself! Thus scientists invariably rely on inductive reasoning at some point, unless they are working in pure mathematics or certain fields of theoretical physics.

A researchers typically generates a testable hypothesis [1] and designs an experiment [2] to observe the results [3], to support a particular theory. This process is inductive.

J. Thompson's Cathode Ray-Experiment [4]is an excellent example of this process. Thompson had ideas about how electrons behaved and generated a theory about their nature. He began with hypotheses [5], designed experiments and tried to find conclusive [6] answers to add credence and weight to his initial theory.

Another excellent example of this process in action is the work of the great Charles Darwin. He made some observations about how Darwin Finches [7] varied across the islands of the Galapagos archipelago.

After some thought and reasoning, he saw that these populations were geographically isolated from each other and that the variation between the sub-species varied over distance. He therefore proposed that the finches all shared a common ancestor, and evolved and adapted, by natural selection, to exploit vacant

ecological niches. This resulted in evolutionary divergence and the creation of new species, the basis of his *Origin of Species.*

This was an example of inductive reasoning, as he started with a specific piece of information and expanded it to a broad hypothesis [5]. But he then also used deductive reasoning [8] to generate testable hypotheses [1] and structure the internal logic of his experiments.

Generally speaking, inductive reasoning and deductive reasoning are a circular process and inextricably linked.

Science Use Both Induction and Deduction

These two styles of reason should be seen as complementary, with inductive reasoning generating support for a theory, and deduction validating or falsifying [9] the internal logic of that theory. This, in turn, leads to inductive enhancements of the theory and more testing.

For example, Bohr used Thompson's experiments as observations about atomic structure. Inductive reasoning [10] led to the creation of theories and hypotheses about the structure and nature of atoms. This is an example of induction taking initial observations and expanding them into full-blown theories.

Deductive reasoning was then used to create individual, logical hypotheses, isolating parts of the theory and testing them, to prove that his ideas were scientific truth. This is an example of the inductive/deductive cycle in action. As a loose rule, inductive reasoning is used to try to discover a new piece of information; deductive reasoning is used to try to prove it.

Links
[1] https://explorable.com/hypothesis-testing
[2] https://explorable.com/design-of-experiment
[3] https://explorable.com/statistically-significant-results
[4] https://explorable.com/cathode-ray-experiment
[5] https://explorable.com/research-hypothesis
[6] https://explorable.com/drawing-conclusions
[7] https://explorable.com/darwins-finches
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[10] http://www.cdtl.nus.edu.sg/ctp/inductive.htm