What is a Scientific Theory?

In science, *theory* means a reliable explanation of some phenomenon supported by a vast body of knowledge and unlikely to be substantially changed by new information. Scientific theories must also be falsifiable—that is, it must be possible for a theory to be shown to be wrong (National Academy of Sciences, p.2, 1999).

Question: Is it the same as a guess?

No, in fact a scientific theory is the opposite of a guess: it is the most reliable explanation available, consistently leading to accurate predictions. This can be confusing, because the word ‘theory’ is commonly used to describe a hunch. In science, an explanation only becomes a theory if it meets certain criteria.

Criteria for a Theory:

- ☑ **Falsifiable but not falsified.** It must be possible to demonstrate a theory is incorrect or deficient. Theories must be testable because so that we can be confident in their predictions (Elmes et al., 2006).

- ☑ **Predictive.** A theory must make predictions that *could* be found to be incorrect but are, instead, consistently shown to be accurate across a large area of inquiry (as cell theory is to biology, for instance). In fact, it is by making predictions that are later found to be true that *hypotheses*, or testable statements based on reason and observation, come to be theories (Elmes et al., 2006).

- ☑ **Modifiable.** There is always room to improve our understanding of reality. Even very powerful theories may not give satisfactory explanations of certain phenomenon (Elmes et al., 2006). Rather than start over, though, theories often are changed slightly to better approximate reality, resulting in a stronger theory (see sidebar, *How Theories Develop*).

- ☑ **Simple.** There may be infinite, and infinitely convoluted, possible explanations for even the most basic phenomenon, but a simple answer is more testable. Note that this criterion is more a heuristic (rule of thumb) than the others. A simple theory is *more likely* to be useful and valid, but a complicated theory could be useful if it meets the other criteria (Baker, 2004).

How Theories Develop: The Story of Continental Drift

In the 1590s, geographer Abraham Ortelius proposed that the continents had moved over time. Francis Bacon echoed this view in 1620, as did various others, but the idea was not accepted until a German meteorologist and geophysicist name Alfred Wegener described his theory of *The Origin of Continents and Oceans* in 1915.

Wegener found supporting evidence in the jigsaw-puzzle-like shape of the continents and the similarity of geology on both sides of the Atlantic, including coal deposits that would have been continuous had the continent never moved. This became known as the theory of continental drift, and evidence from paleontology (fossils of some species are found on both sides of the Atlantic but nowhere else in the world) and climatology (glacial deposit in India and the southern continents only make sense if they had all been together when the glaciation took place). Though Wegener’s explanation was the most logical explanation for all these coincidences, it was widely rejected. Scientists could not believe that rock could plow through rock, and Wegener failed to explain *why* the continents drift.

Over time, new evidence elucidated the mechanism: heat from the earth’s core causes molten rock to rise, then cool, before eventually plunging back down to continue the cycle. Plate tectonics explains mountain formation, vulcanism (volcanoes), the topography of the ocean floor, seismology (earthquakes), as well as other phenomenon including the coincident distribution of rocks and fossils on either side of the Atlantic Ocean. Though Wegener’s theory has been replaced by the theory of plate tectonics, his explanation was the best available at the time and became stronger as it became integrated into a larger—and still growing—body of knowledge (McKnight & Hess, p.375-387).

A reproduction of the 1957 map by Marie Tharp depicting ocean topography and revealing evidence of seafloor spreading. This discovery decisively settled the debate: continental drift became a fact. *Credit: David Rumsey (davidrumsey.com)*

Question: Is a scientific theory fact?

Yes, but the term 'fact' deserves some discussion. In science, fact usually means something that has been observed. If we weighed something, for instance, its weight would be a fact. In this sense, a theory is a generalization based on an enormous accumulation of facts, but not really a fact itself. However, there is another meaning: a thing that has been so consistently supported by the evidence, and for so long, that no good reason remains to continue to directly test its validity. In this sense a scientific theory is indeed a fact (*Evolution*, 2018).

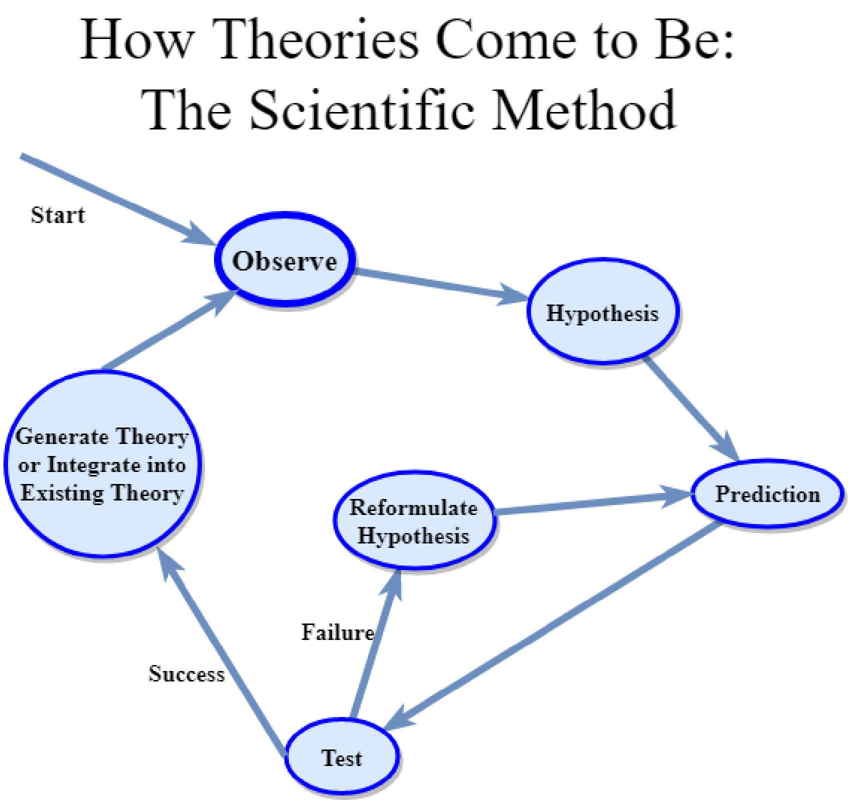

Figure 1. Scientific theories are evolving concepts and part of a greater body of knowledge.

Key Points:

- An explanation becomes a scientific theory when the evidence supporting it is so extensive that it becomes fact.
- Theories represent something real without *being* reality, the same way a map represents a place.
- Theories are improved over time as new evidence becomes available.
- It must be possible—though it is highly improbable—that a theory could be shown to be incorrect.

References

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